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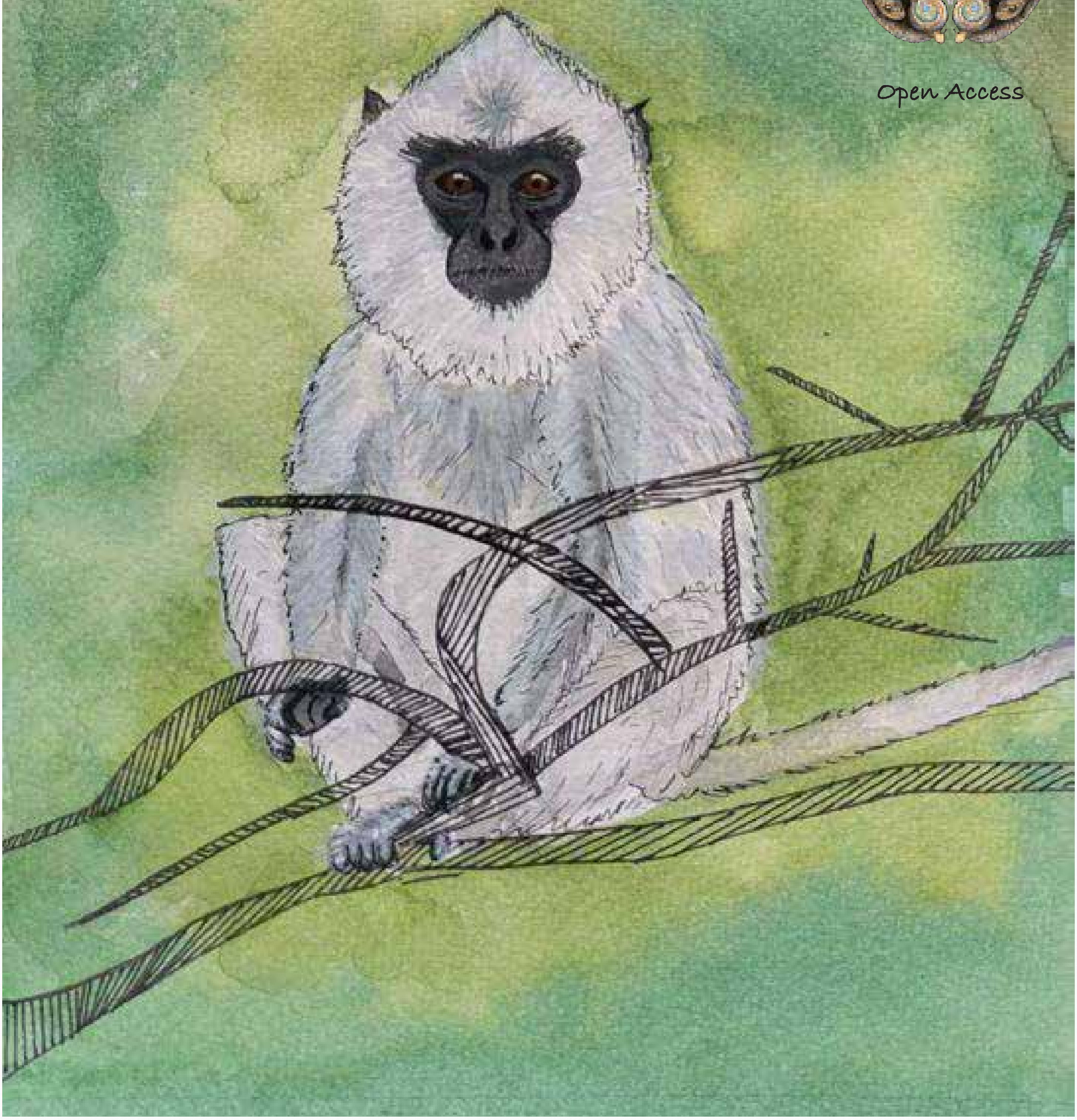

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Cover: Coromandal Sacred Langur *Semnopithecus priam* - made with acrylic paint. © P. Kritika.

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ARTICLE

Group densities of endangered small apes (Hylobatidae) in two adjacent forest reserves in Merapoh, Pahang, Malaysia

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Abstract: Small ape habitat is rapidly declining due to anthropogenic activities but the current population status of this endangered primate family in Malaysia remains unknown. Group densities of *Hylobates lar* and *Symphalangus syndactylus* in two adjacent forest reserves across the Sungai Yu Ecological Corridor (SYEC) in Merapoh, a critical connectivity area of the Central Forest Spine, were assessed. Vegetation assessment and satellite imagery were used to identify habitat characteristics and fixed-point active acoustic triangulation at six listening areas was conducted to estimate small ape group densities. Small ape habitat quality was high in the forested areas of the SYEC. The mean group density of *H. lar* across these six areas was 3.55 ± 0.9 groups km^{-2} while the mean group density of *S. syndactylus* was 2.75 ± 1.0 groups km^{-2}. The mean group densities of small apes at SYEC were moderately high, compared with densities at other sites in the region, which suggests that the forests here constitute good habitat for both species, despite some observed anthropogenic disturbances. Both species occurred in all listening areas. A nationwide population census for small apes and regular monitoring to inform conservation planning are recommended. Further improvement to connectivity across the SYEC by installing artificial canopy bridges for arboreal animals is important to support the movement of small apes across habitat fragments in Merapoh.

Keywords: Central Forest Spine, conservation, ecological corridor, endangered, gibbons, *Hylobates lar*, population density, primate, Sungai Yu Ecological Corridor, *Symphalangus syndactylus*, vegetation.

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INTRODUCTION

Wildlife populations are declining worldwide due to anthropogenic actions that cause large-scale habitat destruction, disturbance, and fragmentation (Laidlaw 2000; Phoonjampa & Brockelman 2008; Estrada et al. 2017; 2019; Hughes 2017). The survival of forest-dependent animals, especially primates, strongly depends on the quality of their habitat (Lucas & Corlett 1998; Chapman et al. 2006; Link & Di Fiore 2006) as intact forests provide essential resources including food, secure sleeping sites, protection from predators, and pathways for arboreal movement (Johns 1986; Bartlett 2010). Habitat disturbance in forested landscapes can negatively affect arboreal species due to the creation of canopy gaps from the loss of trees and the reduction of woody climbers, which hinders their movement (Phoonjampa et al. 2011).

Peninsular Malaysia has four major forest complexes, which together are known as the Central Forest Spine (CFS). The forests in Merapoh, Pahang, are a critical ecological corridor of the CFS and form the last linkage between the two largest forest complexes in Peninsular Malaysia: the Titiwangsa Range and Taman Negara Landscape (Meisery et al. 2020, Image 1). The government and several non-governmental organizations have been working together in Merapoh to realize the Sungai Yu Ecological Corridor (SYEC) Project. This corridor comprises two forest areas, which include the Tanum Forest Reserve (to the east on the Taman Negara side), separated from the Ulu Jelai and Sungai Yu Forest Reserves (to the west on the Main Range side) by the Kuala Lipis – Gua Musang Road. Along the road, three eco-viaducts have been constructed, starting in 2009, to facilitate forest connectivity and safer wildlife crossings (Meisery et al. 2020). Ecological connectivity is important for wildlife to thrive as it allows animals to move between habitat sites to find food, breed and establish new territories. Habitat connectivity can influence the distribution, genetic diversity, and health of populations (Gibbs 2001). However, management strategies formulated for large terrestrial umbrella species may not be appropriate for arboreal animals that depend on undisturbed canopy cover to effectively disperse.

Small apes (Hylobatidae) or gibbons are highly arboreal and rely on continuous and dense canopy cover for locomotion (Cannon & Leighton 1994). Even small gaps in the canopy can hinder small ape movement and dispersal (Cheyne et al. 2013; Asensio et al. 2021). Small apes occur in evergreen forests of South and Southeast Asia and southern China and are classified into four genera: *Nomascus*, *Hoolock*, *Hylobates,* and *Symphalangus* (Zihlman et al. 2011) with members of the latter two inhabiting the SYEC: Siamangs *Symphalangus syndactylus* (Raffles, 1821) and White-handed/Lar Gibbons *Hylobates lar* (Linnaeus, 1771). Siamangs live sympatrically with Lar Gibbons (or the other sympatric small ape species Agile Gibbons *H. agilis*) across almost their entire distribution range in Sumatra and Peninsular Malaysia (O'Brien 2003). The home ranges of small apes are typically around 30 ha (ranging from 5 to over 100 ha), and they usually defend all or parts of these areas as territories (Chivers 1977; Palombit 1993). However, neighbouring groups may partially share their home ranges (Cheyne et al. 2019). Small apes may intrude into the territory of neighbouring groups to feed (Gittins 1980). A study on a habituated group of *H. leuconedys* in Gaoligongshan, Yunnan, China, found that this small ape species shifted its home range according to the seasonal availability of food species (Zhang et al. 2014).

Home ranges of Siamangs are usually smaller than those of Lar or Agile Gibbons (Caldecott 1980) and although they are ecological competitors (Palombit 1997; Elder 2013), both species can thrive sympatrically due to differences in their body sizes (Lar Gibbon mean female body mass is 5.34 kg; Siamang mean female body mass is 10.5 kg; Smith & Jungers 1997) and they differ in their nutritional adaptations (Raemaekers 1978). Although they use many of the same food species and forage in similar forest strata, they exhibit slight differences in their ecological niches due to their dietary needs and preferences and their reliance on different fallback strategies (Elder 2009). All small apes are highly frugivorous (MacKinnon & MacKinnon 1980; Elder 2009, 2013) and are effective and important seed dispersers in Asian rainforests (McConkey 2009). They often rely heavily on figs (*Ficus* spp.), which function as staple or fallback foods in tropical forests (Marshall et al. 2009). Small apes are recognized for their ability to adapt and persist in certain degraded forests, even though these habitats may have fewer large food and sleeping trees and exhibit discontinuous canopies (Cheyne et al. 2013).

In their natural habitat, small apes typically form small groups consisting of an adult male-female pair (Srikosamatara 1984; Leighton 1987) and up to four offspring (Phoonjampa & Brockelman 2008). The breeding pairs frequently engage in coordinated duets (Brockelman & Ali 1987; Brockelman & Srikosamatara 1993) that can be heard up to one kilometre away if the sound is not obstructed by landscape features (Mitani 1987). Each small ape species produces different songs; thus, Lar Gibbon and Siamang calls are easily distinguishable, and pairs can be distinguished from solitary individuals because the female 'great call' is only performed by paired females (Haimoff & Gittins 1985). Relying on visual detection and identification of small apes is problematic, as unhabituated animals often hide or quickly flee when they encounter humans, and under low light conditions or while moving rapidly, the different species can appear similar in habitus. Because of the challenges involved in visually detecting small apes, coupled with the relative ease of using songs to detect and identify small ape species, acoustic surveys are the standard method for small ape population surveys (Brockelman & Ali 1987; Brockelman & Srikosamatara 1993).

Despite their ecological importance and the relative ease of acoustic detection methods, the population status of all five Malaysian small ape species remains critically understudied. All Malaysian small ape species are listed as 'Endangered' in the IUCN Red List (*S. syndactylus*, Nijman et al. 2020; *H. lar*, Brockelman & Geissmann 2020; *H. agilis*, Geissmann et al. 2020; *H. funereus*, Nijman et al. 2020; *H. abbotti*, Cheyne & Nijman 2020). Thus, information about the abundance of these threatened species will provide a crucial baseline for ongoing population monitoring, and is needed for development of data-based conservation strategies (Sutherland 2000) specifically targeted at preserving small apes in Malaysia. Thus, the specific objectives of this study were: 1) to estimate group densities of Siamangs and Lar Gibbons in two forest reserves in the SYEC landscape, i.e., the Sungai Yu Forest Reserve and Tanum Forest Reserve; 2) to compare small ape densities and habitat quality in Tanum FR, which is contiguous with the large, totally protected area of Taman Negara Pahang, with those in forests of equivalent elevation in Sungai Yu FR, which has experienced significant disturbance from mining and timber extraction and is almost a habitat island; and 3) to determine the relationship between Siamang and Lar Gibbon group densities to assess the importance of interspecific competition as a factor limiting their populations.

MATERIALS AND METHODS

Study site and period

This study was conducted in two adjacent forest reserves, which both host Siamangs and Lar Gibbons, but have different levels of disturbance. Both reserves are situated within the SYEC (also known as Merapoh Forest Complex Pahang; coordinates 101.951863–102.014998 E & 4.606160–4.543659 N) and are separated by the Kuala Lipis – Gua Musang road in the state of Pahang in Peninsular Malaysia. The Tanum Forest Reserve (FR) is considered more pristine and is contiguous with the Taman Negara National Park, which is a large, protected area with relatively intact forest. The Sungai Yu FR (Appendix 1) is connected to the Titiwangsa Range, which serves as an important ecological corridor for tigers and other threatened species in Peninsular Malaysia. While parts of the Sungai Yu FR have experienced disturbances due to the construction of logging roads and mining, the area still maintains some form of connectivity with other disturbed forests. Both forest reserves contain mostly lowland forest vegetation <400 m, although the western parts of Sungai Yu FR, which were not surveyed, contain some higher-elevation forests.

Data were collected from February to March 2018 with the help of trained field assistants. Four listening areas (LA; Sungai Yu, Kubang Rusa, Campsite, and Jelangat) in Sungai Yu FR, and two LA's (Tanum1 and Tanum2) in Tanum FR, with three distinct listening posts (LP) in each LA (Image 2) were constructed. The LPs were established ca. 500 m apart, arranged in an approximately equilateral triangle to facilitate detection of duet songs within the LA from multiple LP as often as possible, and their exact locations were recorded with a Garmin GPSMap 64s. Approximate LP locations were planned on the map ahead of the survey, but the exact LP locations were adjusted in the field as needed to avoid impassable vegetation and deep valleys where vocalizations may be missed or direction misinterpreted (Hamard et al. 2010). This resulted in slight size variation of the sampling areas at each LA (Phoonjampa et al. 2011).

Habitat vegetation characteristics

Following Hamard et al. (2010), ten 10 m x 10 m in situ vegetation 'speed plots' were established in each LA around the LPs. Three plots were placed 50 m away from each LP, with one each to the north (0°), south-east (125°), and south-west (225°) of the LP, and the tenth plot was placed near the centre of the three LPs.

In each plot, the (1) estimated canopy cover (scored visually using a GRS Densitometer™; estimated from three points within the plot; rounded to the nearest 5%), (2) diameter at breast height (DBH) of all trees >10 cm DBH, (3) height of all trees >10 cm DBH, (4) total number of trees >10 cm DBH, (5) tree species (if known), and (6) elevation (m) were recorded. Tree basal area was calculated as the sum of basal areas for all trees in

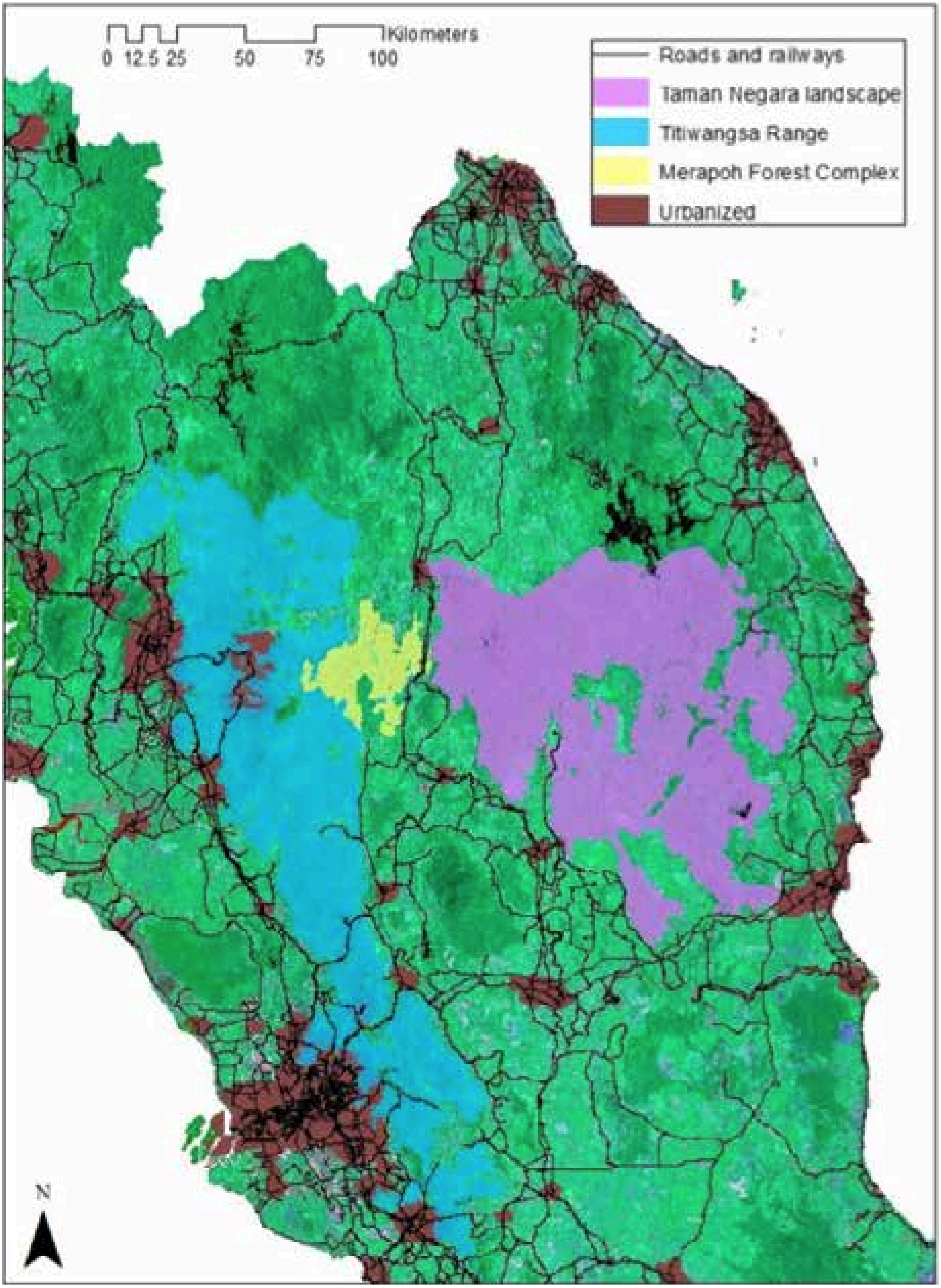

Image 1. Central Peninsular Malaysia showing the major forest complexes (blue: Titiwangsa Range; purple: Taman Negara Landscape) and the position of the Merapoh forest complex (yellow) as a crucial linkage between these landscapes. The background is a composite Landsat image (Hansen/UMD/Google/USGS/NASA) showing the 2018 forest cover (Hansen et al. 2013).

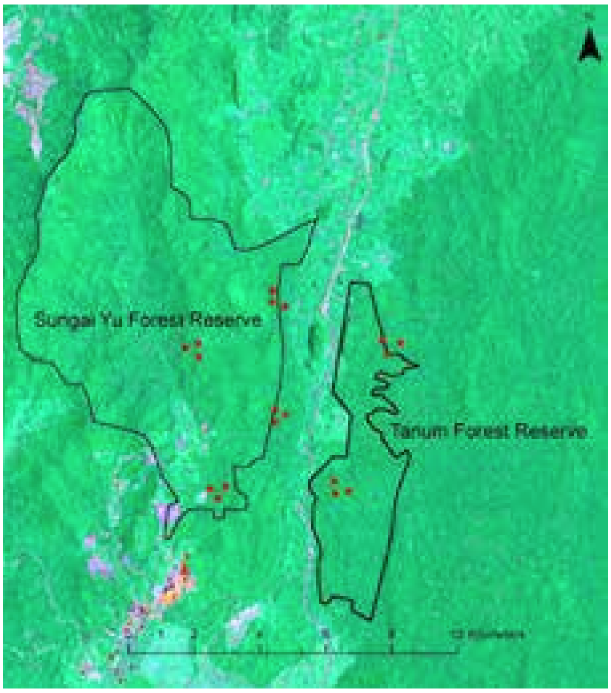

Image 2. Study sites in SYEC with the positions of the three listening posts (red dots) associated with each of the six listening areas. The background is a composite Landsat image (Hansen/UMD/Google/USGS/NASA) showing the 2018 forest cover (Hansen et al. 2013).

each plot. The basal area for each tree was estimated as (DBH/2)2 x π. Not all trees could be identified to species level by a botanist who was provided with clear photographs of leaf undersides and leaf arrangement, flowers, fruits and bark for species identification, so these data could not be used for further analysis. All vegetation characteristics were averaged for each LA. The mean DBH, tree height and canopy cover were calculated and compared among LAs using the Kruskal-Wallis Test, and between Sungai Yu and Tanum using the Mann-Whitney U test.

Remotely sensed data. Habitat quality in each LP and each FR was also assessed using remotely sensed data from open-access satellite imagery. ArcGIS (Esri, Redlands, CA) was used to match the location of each LA and each FR, with forest cover data from 2000 to 2018 from composite Landsat images (Hansen/UMD/Google/USGS/NASA) to estimate the percentage of forest cover in 2000 and forest loss from 2000 to 2018 (Hansen et al. 2013). Elevations of the study sites were measured using a Digital Elevation Model (DEM) from the National Aeronautics and Space Administration/Ministry of Economy Trade and Industry/ Advanced Industrial Science and Technology/Japan Spacesystems & U.S./Japan ASTER Science Team (2018) to estimate the mean elevation for each LA.

Small ape group density assessment

Acoustic surveys: The population density of small apes in Sungai Yu FR and Tanum FR was estimated using active acoustic survey techniques (Brockelman & Srikosamatara 1993). Only those groups that produced at least one female great call and the male's responding call (which is indicative of a pair/group) in the analyses to avoid counting solitary individuals (Cheyne et al. 2008) were included. Two observers were stationed together at each of the three LPs inside one LA for three consecutive mornings from 0700 until 1200, which are the peak calling periods for small apes in Peninsular Malaysia. When duet songs were detected, the observers recorded the compass bearing, start and stop time, and estimated distance from the LP to the duetting pair. After the assessment of one LA was completed, the six observers moved to the next LA.

Group density analysis: To determine the number of small ape groups detected at each site, the location of each duet was triangulated based on the intersection of lines originating from three adjacent LPs. The intersecting lines were mapped in ArcGIS software. Using satellite imagery and a Digital Elevation Model (DEM), the rivers, plantations, residential areas, roads and deforested areas were removed to measure the total sampling area of effective small ape habitat at the study sites.

Group density was then estimated following Brockelman and Ali (1987), as:

$$D = n / [p (m) \times E]$$

where n is the number of groups heard at each sample site, $p(m)$ is the estimated proportion of groups expected to sing during a sample period of m days, and E is the sample area. The sampling area was calculated as follows. First, the total potential LA was defined as the area within a fixed radius of 1 km from each LP, which is roughly the maximum distance at which duets can be heard in a closed forest. Then, all areas within this LA that were acoustically occluded by terrain features, such as areas that were effectively behind a hill were excluded. A one-tailed Spearman correlation was used to assess the relationship between Lar Gibbon and Siamang group densities in the LA.

RESULTS AND DISCUSSION

Habitat characteristics

Habitat characteristics in the vegetation plots are shown in Table 1. There were no significant differences among LA in tree number (X = 5.923, df = 5, p = 0.314), DBH (X = 9.277, df = 5, p = 0.099), tree height (X = 8.445, df = 5, p = 0.133), basal area (X = 7.633, df = 5, p = 0.178), or canopy cover (X = 5.114, df = 5, p = 0.402). Similarly, there were no significant differences in habitat characteristics between Tanum FR and Sungai Yu FR (tree number: U = 332.5, N_1 = 4, N_2 = 2, p = 0.288; DBH: U = 225, N_1 = 4, N_2 = 2, p = 0.093, tree height: U = 260.00, N_1 = 4, N_2 = 2, p = 0.309; basal area: U = 237, N_1 = 4, N_2 = 2, p = 0.146; canopy cover: U = 192.5, N_1 = 4, N_2 = 2, p = 0.914.) Mean elevation for the six LAs was 244.5 m (range 180–342 m) without significant differences between two forest reserves.

There was no difference among LAs in Sungai Yu FR and Tanum FR in the year-2000 forest cover (U = 3.000, N_1 = 4, N_2 = 2, p = 0.80) or the percentage of forest lost between 2000 to 2018 (U = 3.00, N_1 = 4, N_2 = 2, p = 0.80; Table 2). Satellite image analysis showed that ca. 4% of the Sungai Yu FR forest cover was lost between 2000 and 2018. The deforested area in Sungai Yu FR was heavily concentrated in its southern part. Tanum FR lost 2% of its forest cover between 2000 and 2018, and these losses were concentrated in a narrow band along the western edge of the forest reserve.

The results of the vegetation analysis suggest that habitat quality remained high in the forested areas of both forest reserves, despite substantial recent disturbance in the southern part of Sungai Yu FR, and encroachment on the western edge of Tanum FR The absence of detectable differences in forest cover changes in the LAs likely resulted from our methods for calculating LA area, which excluded areas that had been converted to agricultural, residential, or commercial use, or for transportation corridors, and may also reflect low statistical power. Due to the relatively small sizes of both FR and the concentration of low-elevation forest on the east side of Sungai Yu FR, our sample size was small, and several LA were placed in habitat edges.

Small ape group densities

In total, 121 distinct groups of Lar Gibbons and 101 groups of Siamangs were recorded in a total survey area of 41.9 km² across both forest reserves.

Small ape group densities did not differ between Tanum FR and Sungai Yu FR for Lar Gibbons (t = -0.395, df = 4, p = 0.713) or Siamangs (t = -0.756, df = 4, p = 0.492). The mean group density of Lar Gibbons across the six LAs was 3.55 ± 0.9 groups/km² while the mean group density of Siamangs was 2.75 ± 1.0 groups/km². The density of Lar Gibbons at Sungai Yu LA (5.28 groups/km²) was considerably higher than that of the other LAs (<4.00 groups/km²). However, the Siamang density was highest at Kubang Rusa LA (3.79 groups/km²). No significant relationship between Siamang and Lar Gibbon group densities (ρ = -0.543, N = 6, p = 0.133) at the study site was detected.

Habitat conditions are often predictive of animal densities (Chivers 1984; Marshall, 2010), and relatively high densities of Lar Gibbons and Siamangs were found in both forest reserves, which indicates that this habitat continues to support a substantial population of small apes. This is perhaps unsurprising, as lowland and hill forests (<750 m) generally support higher population densities of *Hylobates* spp. than higher elevation forests (Caldecott 1980; Johns 1986; Brockelman & Ali 1987; Nijman 2001; O'Brien et al. 2004). However, some populations have their highest densities at slightly higher altitudes, especially in areas of sympatry between Siamangs and *Hylobates* spp., where ecological competition between small apes may limit the population of one or both species. For example, at Gunung Benom in Krau Wildlife Reserve, Pahang, Malaysia, Siamangs occurred at a low density below 300 m, were most abundant between 700 m and 1,000 m, and their density declined with increasing altitude up to 1,500 m (Caldecott 1980), whereas Lar Gibbon density decreased with increasing elevation, and Lar Gibbons were not found in forests >1,200 m. Conversely, in Bukit Barisan Selatan National Park in Sumatra, Indonesia, where Siamangs are sympatric with *H. agilis*, Siamang densities were highest in lowland and submontane forests, and *H. agilis* density peaked in mid-elevation forests (O'Brien et al. 2004). A similar pattern is reported in Kerinci Seblat National Park, Sumatra (Yanuar 2001). Despite this apparent tendency for sympatric small apes to use different elevation ranges, our surveys indicated that both species have fairly high densities in the lowland forests of the Sungai Yu Ecological Corridor (SYEC) in Merapoh. Although no significant negative correlation between Lar Gibbon density and Siamang density in Merapoh was found, as would be expected if ecological competition was limiting their populations, this may be due to limited statistical power resulting from the small number of independent samples in our analysis. The correlation coefficient was negative, and high (>0.5), which is consistent with this explanation. Nonetheless, both species were detected in all LA, and group locations suggested considerable overlap in habitat use.

The mean density of Lar Gibbon and Siamang groups (with 3.55 groups/km² and 2.75 groups/km², respectively) in SYEC can be considered as moderate or moderately high, which suggests that the forests are of relatively

Table 1. Vegetation characteristics in the six listening areas (LAs) in Merapoh, Pahang.

Forest reserve	Listening area (LA)	Mean tree number (>10 cm DBH)	Mean DBH (cm)	Mean tree height (m)	Total tree basal area (cm²)	Mean % canopy cover
Sungai Yu	Campsite	5.6	19.7	13.0	2,176.2	53.6
	Jelangat	3.3	26.3	15.4	2,990.0	65.0
	Kubang Rusa	5.3	24.3	13.0	5,086.4	55.5
	Sungai Yu	5.8	24.7	17.2	3,456.6	65.0
Tanum	Tanum1	6.4	24.7	15.5	3,679.7	73.5
	Tanum2	4.8	29.9	15.3	4,654.2	59.6

Table 2. Remotely sensed forest cover data. Values are percentages of the area forested in 2000 (defined as having at least 30% forest cover at 5 m) and percentages of the area forested in 2000 that was lost (defined as a total stand clearance in a 30 x 30 m pixel) between 2000 and 2018.

Forest reserve	Listening area (LA)	Forest cover percentage in the year 2000	Total forest cover loss percentage from 2000 to 2018
Sungai Yu	Sungai Yu	100	0.9
	Jelangat	99.4	0.3
	Campsite	100	0
	Kubang Rusa	98.9	0
Tanum	Tanum 1	98.8	0.2
	Tanum 2	100	0

good habitat quality for both small ape species, despite the disturbances caused by logging for the conversion to rubber plantations, oil palm plantations, highways, railways, and villages, as well as selective logging and mining in the Sungai Yu site. Small apes are reported to adapt to slight disturbances by shifting their use of canopy to the lower canopy layers (Johns 1986; Nijman 2001) and changing their diets and adjusting activities to reduce energy costs (Johns 1986; O'Brien et al. 2003).

Small ape densities did not differ between Sungai Yu FR and Tanum FR. Sungai Yu FR is separated from Tanum FR by a highway and adjacent cleared areas but is contiguous with several forest reserves that have been degraded and fragmented, while Tanum FR is connected to the larger protected forests of Taman Negara Pahang. The estimated rate of forest loss in Sungai Yu FR between 2000 and 2018 was twice as high as in Tanum FR. Nonetheless, our density estimates for small apes in Tanum FR were not higher than those for Sungai Yu FR. This may be because most of our LAs in the Sungai Yu FR were in the central area or along the eastern edge of the forest reserve, whereas recent encroachment and disturbance are concentrated in the southern part of the forest reserve.

The smallest LA in our sample was Sungai Yu (3.06 km²), which included substantial areas that have been completely cleared of trees since 2010. When small ape groups experience habitat loss, the group densities may increase temporarily due to a 'compression effect', as animals are displaced from degraded or deforested areas and concentrated in the remaining forested areas (O'Brien et al. 2003; Cheyne et al. 2016, 2019; Pang et al. 2022). Thus, the relatively high density of Lar Gibbon groups recorded in the Sungai Yu LA may reasonably be interpreted as reflecting population compression due to recent habitat disturbance and loss in the area. However, continuous monitoring over at least a decade would be needed to determine the long-term fate of the small ape groups in the area.

Thus, despite our finding that small apes persist at moderately high densities in the SYEC, there is reason for concern. Small ape dispersal can be restricted in fragmented forests because gibbons rarely descend to the ground (Cannon & Leighton 1994; Cheyne et al. 2013), even to cross relatively narrow gaps in the forest canopy (Asensio et al. 2021). As a result, populations in small fragments can become isolated (Cheyne 2019), increasing the risk of small population processes such as inbreeding depression (O'Grady 2006; Geissmann 2007). Ongoing habitat degradation and fragmentation in the SYEC/Merapoh Forest Complex, especially on the periphery and interior of Sungai Yu FR, may therefore pose a threat to the long-term viability of small apes in this landscape.

The Malaysian government recognizes the importance of the SYEC as a vital linkage between the wider Taman Negara landscape and the Titiwangsa Range forests and has been working with several NGOs to develop and implement a wildlife corridor project here, whereby in 2009, an eco-viaduct in form of an underpass was built to enhance movement of terrestrial animals across the SYEC landscape to encourage safer wildlife crossings between forests (IC-CFS 2021). However, an underpass is unlikely to enhance the movement of arboreal animals across the estimated 500 m wide forest gap here.

Natural connectivity via appropriate vegetation is usually the best way to support the movement of arboreal animals, and every attempt should be made to maintain canopy connectivity and to restore it when anthropogenic disruptions occur. Where that is not possible, artificial arboreal wildlife crossing structures or canopy bridges have been built in many locations worldwide to mitigate the habitat fragmentation impacts on threatened treetop-dwelling wildlife and to re-establish habitat connectivity (e.g., Weston et al. 2011; Gregory et al. 2013; Teixeira et al. 2013; Yokochi & Bencini 2015; Balbuena et al. 2019). For example, an artificial canopy bridge installed in Hainan, China effectively facilitates the movement of a group of Hainan Black Crested Gibbons *Nomascus hainanus* across a forest gap created by a landslide (Chan et al. 2020). Malaysia's first urban canopy bridge was built in Teluk Bahang, Penang, to facilitate the safe crossing of a busy highway by endangered Dusky Langurs *Trachypithecus obscurus* and Long-tailed Macaques *Macaca fascicularis* that had previously been frequent victims of vehicle collisions. From its installation in April 2019 to May 2021, it was used in 2,028 road crossings by Dusky Langurs (21 crossings), Long-tailed Macaques (32 crossings) and Plantain Squirrels (*Callosciurus notatus*; 2,075 crossings; Yap et al. 2022). These and other examples indicate that properly designed artificial structures can facilitate the movement of arboreal animals across roads and other linear gaps in the forest.

The highway that bisects the SYEC in Merapoh creates a substantial barrier to the movement of arboreal animals, which increases the risks of local extinctions and loss of ecological services in increasingly disturbed and fragmented landscapes. To mitigate this risk, artificial canopy bridges or similar interventions for arboreal animals should be developed to complement the eco-viaduct underpass. Together with other mitigation strategies to facilitate animal movement, this could improve ecosystem health across the SYEC and the Titiwangsa and Taman Negara forest complex.

CONCLUSION

Small apes can adapt relatively well to small changes in habitat conditions and the Merapoh Forest Complex is still a good lowland forest habitat for small apes. The moderately high group densities detected in all forest sites sampled emphasize the importance of this degraded forest as a habitat for small apes. Because of the threats to small apes in Malaysia, and the uncertain status of most populations in the country, a nationwide population census and regular monitoring to inform conservation planning and implementation is strongly recommended. Importantly, the study calls for the improvement of the Sungai Yu Ecological Corridor (SYEC) Project to support the movement and persistence of populations of small apes and other arboreal wildlife across the landscape by restoring forests where possible and installing artificial canopy bridges where necessary to connect forests and habitat fragments in Merapoh.

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Abstrak Bahasa Malaysia: Aktiviti manusia telah mengancam habitat mawas kecil dengan pantas, namun status populasi semasa keluarga primata ini di Malaysia masih tidak diketahui walaupun ia telah terancam diseluruh dunia. Ketumpatan kumpulan *Hylobates lar* dan *Symphalangus syndactylus* telah dinilai di dua hutan rizab sepanjang Koridor Hidupan Liar Sungai Yu (KHLSY) di Merapoh, dimana ia merupakan kawasan ketersambungan kritikal gugusan kompleks hutan, iaitu 'Central Forest Spine'. Penilaian tumbuh-tumbuhan dan pengimejan satelit telah digunakan untuk mengenal pasti ciri habitat dan triangulasi akustik aktif yang mempunyai titik tetap di enam kawasan mendengar telah dijalankan untuk menganggarkan kepadatan kumpulan mawas kecil. Kualiti habitat mawas kecil lebih tinggi di kawasan berhutan KHLSY. Purata ketumpatan kumpulan *H. lar* merentasi enam kawasan ini ialah 3.55 ± 0.9 kumpulan km^{-2} manakala purata ketumpatan kumpulan *S. syndactylus* ialah 2.75 ± 1.0 kumpulan km^{-2}. Purata kepadatan kumpulan mawas kecil di KHLSY adalah sederhana tinggi, berbanding dengan ketumpatan di tapak kawasan lain. Ini menunjukkan bahawa hutan di sini merupakan habitat yang masih baik untuk kedua-dua spesis, walaupun telah terganggu oleh aktiviti manusia. Kedua-dua spesis ada di semua kawasan kajian yang telah dijalankan. Maklumat banci kepadatan mawas kecil dan pemantauan berkala di seluruh negara untuk perancangan pemuliharaan adalah amat digalakkan. Penambahbaikan lanjut kepada ketersambungan merentasi KHLSY dengan memasang jambatan kanopi tiruan untuk haiwan arboreal adalah penting untuk menyokong pergerakan mawas kecil merentasi habitat yang telah terpisah di Merapoh.

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Author contributions: ASK designed the research, carried out the fieldwork and data analysis, and wrote and revised the article. NIAMR carried out the fieldwork and approved the submission. SL conceptualised the central research idea, designed the research, provided the theoretical framework for the research, provided comprehensive training in data analysis, supervised research progress, revised all article drafts, and approved the submission. TQB conceptualised the central research idea and designed the research, revised the article drafts, and approved the submission. NFNR supervised the research progress, revised the final article, and approved the submission. SAMS facilitated research logistics and supervised research progress, revised the final article draft, and approved the submission. NR conceptualised the central research idea, designed the research, provided the theoretical framework for the research, facilitated logistics, supervised research progress, revised all article drafts and handled the submission.

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ARTICLE

Population demography of the Blackbuck *Antilope cervicapra* (Cetartiodactyla: Bovidae) at Point Calimere Wildlife Sanctuary, India

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Abstract: Demographic research utilizing vital rates and life tables is a standard aspect of planning protection and management strategies for wildlife populations. The Blackbuck *Antilope cervicapra* population at Point Calimere Wildlife Sanctuary, Tamil Nadu, has undergone fluctuations in recent decades. The cause remains elusive, and conservation efforts may be hampered by a lack of population data. This study aimed to estimate demographic parameters using population count and age-sex classification data collected for the years 2017–2020. The overall mean population estimate derived from line-transect distance sampling was 719, with annual estimates of 716, 727, 711, and 722 for the years 2017–2020 respectively. In total, 64% of Blackbucks counted were adults, 19% subadults, and 17% fawns. Mortality was highest for adult and subadult classes for the composite female class, and fawn mortality was 20%. The net reproductive rate (R_0) was as low as 3.28 offspring per generation contrasted with a rather longer mean generation time (G) as 4.75 years. Thus, the study observes a decrease in Blackbuck numbers postulated in earlier research to be driven principally by a conglomerate of factors, including reduction of usable space and interspecific resource competition. Our findings provide a baseline demography of the species and highlights the value of long-term demographic monitoring of age sex classes to understand the evolution of life histories.

Keywords: Age-structure, generation time, fecundity, life table, line transect, monitoring, mortality, reproductive rate, sex ratio.

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Author contributions: SA—data collection, analyses, and draft preparation. SS & SG—data collection, pruning, analyses, and draft preparation. NB—conceptualizing, supervising, data analyses, and final draft preparation

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INTRODUCTION

The Blackbuck *Antilope cervicapra* is a medium-sized sexually dimorphic antelope, with horns borne only by males, which are also more heavily built than females. The species is polygynous, highly social, and exhibits unique lek-mating behavior (Jhala & Isvaran 2016). Moreover, agro-industrial activities have radically altered its natural habitat over the last two centuries. This change is one of the major causes of the reduction and decline in populations within the range of the species. It is reported to be extinct and reintroduced in Bangladesh, Nepal, and Pakistan and introduced populations are found in Australia, Argentina, and USA (Mallon & Kingswood 2001). Presently, the IUCN Red List defines the species as 'Least Concern' (IUCN SSC Antelope Specialist Group 2017), while it is protected under Schedule I of the Indian Wildlife (Protection) Act, 1972.

Point Calimere Wildlife Sanctuary (PCWS) has been noted as a Blackbuck area since the 1800s (Jerdon 1874). After its establishment as a protected area in 1967, substantial efforts have been made to conserve and manage the Blackbuck which then numbered around 600. Until 1995, over 2,300 individuals were reported, after that the population appeared to be diminishing. In 2012 the population declined to 1560 individuals (Baskaran et al., 2016), with a further reduction to a threshold of 700–800 individuals evident during 2017–2020 (Baskaran et al. 2019; Arandhara et al. 2020).

Population declines in the area were due to unregulated hunting in general (Oza & Gaikwad 1973), natural predation by Golden Jackal *Canis aureus*, though only on fawns (Mr S. Sathishkumar, Forester, Vedaranyam Forest Range, April/2018 pers. comm.), however, declines may be suggestive of environmental and demographic stochasticity (Frankham et al. 2004). More recently, sympatric invasive competition and habitat contraction due to invasive *Prosopis juliflora* have been reported as case of decline in PCWS (Arandhara et al. 2020, 2021a).

Numerous research on the species have been undertaken at PCWS, e.g., population size, species interaction, and distribution (Daniel 1967; Nair 1976; Muralidharan 1985; Nedumaran 1987; Ali 2005; Baskaran et al. 2016; Arandhara et al. 2020, 2021b); behavioural ecology (Isvaran 2003, 2007); diet (Baskaran et al. 2016; Frank et al. 2021).

Lack of data on population change and demographics for any population might create an uncertainty about the underlying population process. This forms the basis of species management and conservation, providing information necessary for the evaluation of population trends (Sukumar 1989; Van Horne et al. 1997); life-history parameters (Sinclair 1977; Jhala 1991; Stearns 1992); sexual senescence (Promislow 1991); age-sex specific longevity (Smith 1989); relationships between demographic patterns and social systems (Armitage et al. 1996). Our objective in this study was to understand the demography of the Blackbuck by estimating the following parameters: (i) population size, (ii) age-sex composition, (iii) sex ratio, (iv) fecundity, (v) survival, (vi) mortality, (vii) population change, and (viii) life history parameters.

METHODS

Study area

Point Calimere Wildlife Sanctuary is in Tamil Nadu at the juncture of the Bay of Bengal and Palk Strait. It is situated between 10.27° N, 79.83° E & 10.33° N, 79.84° E, covering about 26.5 km^2. The sanctuary was established in 1967, but it has been identified as a Blackbuck area in scientific records since the 1800. The area receives an average annual rainfall of 1,366 mm, and summer temperature peaks at 37^{o}C and dips to 21^{o}C in winter. Humidity can reach up to 90% on foggy winter mornings (Jan–Feb). The sanctuary is covered by two major vegetation types: (i) tropical dry evergreen and (ii) grassland vegetation. The grassland habitat includes mainland sea beach grassland and salt marsh grassland, preferred by Blackbuck. *Prosopis juliflora* is the only invasive woody plant in the sanctuary. It was introduced in the late 1960 and is reported as harmful to native flora and fauna (Ali 2005; Baskaran et. al. 2019). The feral horse *Equus caballus* and the Chital *Axis axis* are both introduced mammals in the sanctuary and the former is considered invasive (Krishnan 1971; Baskaran 2016). Villagers are allowed to graze their domestic cattle and goats, but large groups are thought to disrupt the Blackbucks' social activity. Also, feral or stray dogs threaten the sanctuary's Blackbucks. Due to its coastal location, the sanctuary has the most human activity in the region, including fishing, firewood collection, and tourist visits (Arandhara et al. 2021b) (Figure 1).

Data collection

Data on age sex composition was recorded from the study area per month annually between 2017 and 2020. Overall, 11 adjacent foot transects (length: 2–4

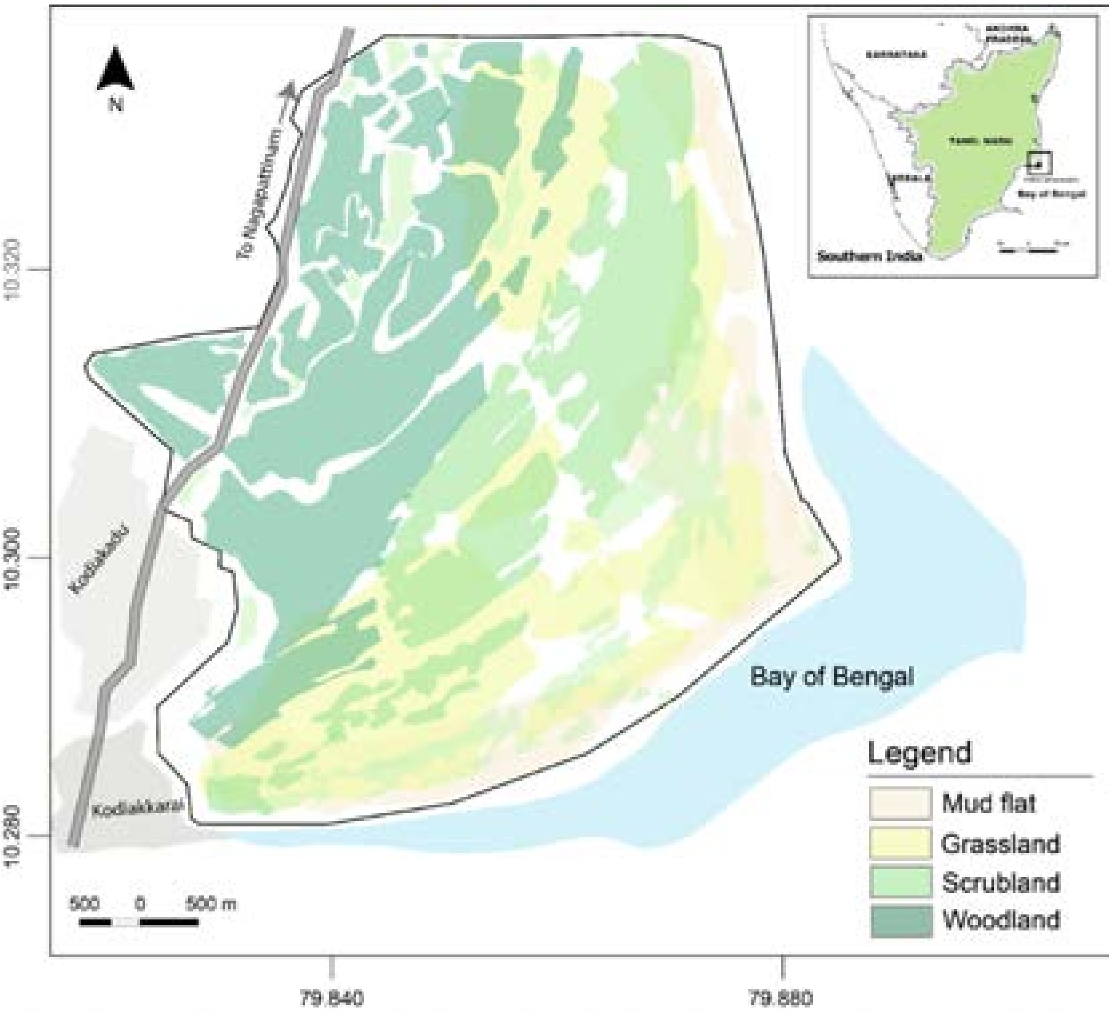

Figure 1. Study area (Point Calimere Wildlife Sanctuary).

km) and 0.5–1 km apart, covered almost the entire 26.5 km^2 extent of PCWS. The number of transect surveys within each month was >2, except a single survey during wet season months. Additionally, data on age sex composition was also collected from other surveys done by the authors (e.g., feeding observations, behavioral sampling). Surveys averaged 3–6 hours in duration, conducted during early morning hours when the Blackbucks are in open grassland and traversing their feeding activities at its peak. Sightings were noted by 1–2 observers, most commonly using binoculars or photographed by digital SLR camera.

If Blackbucks were located on any of the visits, the number of individuals was counted, and their age and sex were assessed according to their coat color and body size, along with horn shape for males. Accordingly, animals were placed in one of three age categories: adult (animals of 2 years and older), subadult (animals between 1 and 2 years), and fawns (young one up to 1 year of age). The juvenile category was dropped due to inconsistency in identification of animals between 6 months and 1 year. The analysis was done for annual data, and therefore we assumed yearly recruitment of the fawns as the next subadult segment.

The age-sex classification was based on Mungall (1978), Ranjithsingh (1989), and Jhala (1991). We kept track on count of fawns by following each adult female, from which fawn mortality could be estimated as difference in number of fawns observed in a year and the subsequent year.

Demographic parameters

Population size

Line-transect distance sampling was used to estimate population size annually (Burnham & Anderson 1976; Marques et al. 2001). The study area was stratified systematically into eight grid cells, measuring 2 × 2 km. Spatially replicated line-transects (length ranging from 0.8–2 km each) were placed one each in the grid cells and surveyed on foot. For estimating density from line-transect data, we used the DISTANCE programme (Version: 7.0, Release: 3 for Windows OS).

Age-sex composition

Count data on sex and age groups were averaged from monthly surveys per year and relative proportion (%) of each age-sex class were obtained for each survey year.

Number of individuals age-sex wise

To derive number of individuals (n) of each age-sex class, annual estimates of population size (N) using distance sampling and % age-sex classes obtained in the previous step.

We estimated (n) by calculating the fraction of year wise % age-sex classes and annual population size estimate (N).

$$n_{AM} = \frac{\%AM}{100} \times N_{2017}$$

Here, n_{AM} is the number of individuals for adult male class in the population.

n is used further for estimation of fecundity rates, survival, and population growth rates based on a Leslie matrix.

Sex ratio

We considered operational sex ratio for adult category as the ratio of sexually active males to females, which itself is the subset of adults that are sexually active. Assuming a 1:1 sex ratio for fawns at recruitment into the adult population, the fawn category was considered equal as sex ratio at birth is equal. We used G^2-likelihood ratio test to check if the observed sex ratio differs from the expected ratio. The study area's 1967 sex ratio (1:1.9) was considered ideal for the population (Daniel 1967).

Fecundity

Fecundity, was estimated as the proportion of fawns produced per adult female, as the number of fawns (per individual of adult females alive at a given time step) censused at the next time step, given as:

$$\text{Fecundity} = \frac{\text{Fawns alive in current year}}{\text{Number of adult females in previous year}}$$

Fecundity estimate is used in estimating and predicting population growth rates (Cole 1954; Henny et al. 1970; Caswell 2001). Blackbucks are reported to produce an average of 1.5 fawns per reproductive female in 12 months (Mungall 1978; Ranjitsinh 1982). At Point Calimere, we observed two fawning peaks, one in early November and another in mid-March.

Survival

Survival rates were defined as the proportion of x-year old individuals that survive to be x+ 1 years old one year later, this definition applies to fawn and sub-adult ages. However, for adult age class which includes individuals ageing 3 and older, a composite class (collapsing the older age classes) is calculated by pooling the counts of subadult and adult age class following Akcakaya (1999) and Caswell (2001).

Mortality

We recorded sources of Blackbuck mortality in two contexts: as incidental observations made during field surveys, and death reports as per personal communications and through records being made after a catastrophic cyclone "Gajah" on the night of 15 November, 2018. The Blackbucks were washed up on the coastlines for roughly 60 km, all the way to the coast of Karaikal, Pondicherry. Using extensive coast surveys, forest department personnel, including the authors, were able to recover 28 carcasses.

The age sex specific mortality rates were estimated from dead carcass counts 'current life table' relative to the population size (Pielou 1977). During 2017–2020, the number of Blackbucks found dead in the study area included 38 females and 19 males, and 18 fawns. As personal communication with the forest department, only nine of the 18 reported dead fawns were able to be sexed. These deaths represented minimum numbers (Sukumar 1989). However, dead fawns are difficult to encounter in field conditions as they were easily preyed upon, moreover the rate of carcass decomposition was faster than in other age-sex classes. Thus, counts of dead fawns were estimated from censuses, as the difference between fawns observed in a census and the number of subadults in the next year census.

Population change (or growth)

We constructed a one-sex, deterministic, density-independent, and discrete time Leslie projection matrix for female age-sex, composed of survival and fecundity rates.

Using this model, annual finite rate of population change (λ) was arrived to project the Blackbuck population throughout the survey period (Akcakaya 1999; Caswell 2001). Additionally, stable age distribution (SAD: point at which the proportion of individuals in each class stays constant each generation, although the population keeps growing); reproductive value (R_v) as measure of the contribution of different kinds of individuals on future population growth assuming individuals of different age classes do not contribute equally to future population growth.

We chose to use this model, assuming that (1) the current population size is not likely to produce a measurable feedback on the vital rates of the population, thus used exponential density dependence (density-independent model), also as the carrying capacity is unknown, we assumed that the Blackbuck density is relatively low (Otway et al. 2003); (2) the population is closed; i.e., there is no immigration or emigration; (3) model only represents the female component of the population and thus presumes that there is no lack of males who can inhibit reproductive potential; (4) all individuals in a given age-stage are subject to identical mortality, growth, and fecundity schedules.

Life history parameters

Life history parameters were arrived from indirect estimation of life-table on females based on mortality adjusted for known rate of population change (Caughley 1967; Sinclair 1977; Jhala 1991; Krebs 2010).

The carcasses obtained at sub-adult and adult segments were age sex identified, assuming no bias in ages at death. However, fawn mortality counts were estimated from censuses (mentioned earlier).

Fecundity schedules were obtained from the literature (Mungall 1978; Ranjitsingh 1982; Jhala 1991). Age-specific probability of surviving (lx), probability of dying (dx), mortality rates (qx), and fecundity rates (mx) were calculated following Sinclair (1977). The population change rate ($r = \ln(\lambda)$) estimated from the Leslie matrix for the study period was used for the cohort corrected for changing population size. Using this life table, we estimated net reproductive rate (R_o—as the mean number of female offspring produced per female over her lifetime); mean generation time (T_c—as the mean age of reproduction); and intrinsic rate of natural increase (r_m).

RESULTS

Population size

Annual population size estimation based on line-transect distance sampling yielded a mean estimate of 719 individuals for the period 2017–2020, with annual estimates of 716 ± 146.7 individuals for 2017, 727± 162.9 for 2018, 711± 145.5 for 2019, and 722± 168.9 for the year 2020 (S-Table 1).

Age-sex composition

The age-sex composition of Blackbuck individuals sampled during 2017–2020 showed that a mean of 64% were adults in the population (AM = 24%; AF = 40%), 19% were subadults (SAM = 4.5%; SAF = 14.5%) and 17.5% were fawns (Table 1; Figure 2). Among the four years sampled, there was no significant difference within the age sex classes, viz., (AM: Kruskal-Wallis test, $X^2 = 3.74$, $p = 2.9$; AF: $X^2 = 2.0$, $p = 0.54$; SAM: $X^2 = 3.7$, $p = 0.28$) but difference was evident in SAF ($X^2 = 8.7$, $p = 0.017$) and FA: $X^2 = 7.4$, $p = 0.5$. During the study, there was no significant trend in either of the age-sex classes (AM: $z = 0.54$, $p = 0.47$; AF: $z = 0.11$, $p = 0.99$; SAM: $z = -0.70$, $p = 0.37$; SAF: $z = -0.25$, $p = 0.93$; FA: $z = 0.1$, $p = 0.87$).

Sex ratio

The adult sex ratio did not deviate significantly for the year(s) 2017, 2018, 2020 and for the combined years the ratio was in favor of the females, not departing

Table 1: Year wise % age-sex composition of blackbuck at Point Calimere WS.

Year	AM (n)	AF (n)	SAM (n)	SAF (n)	FA (n)	Population size (N)
2017	22 (154)	41 (293)	6 (42)	13 (94)	18 (132)	716
2018	22 (158)	40 (292)	4 (30)	14 (93)	21 (153)	727
2019	29 (207)	36 (259)	4 (30)	18 (54)	16 (161)	711
2020	24 (176)	44 (319)	4 (28)	13 (91)	15 (108)	722
Mean ±SE	24.25 ± 1.19	40.25 ± 0.74	4.5 ± 0.43	14.5 ± 1.46	17.5 ± 1.22	719

AM—adult male | AF—adult female | SAM—subadult male | SAF—subadult female | FA—fawn **|** **n**—number of individuals derived from fraction of year wise % age-sex composition recorded through monthly direct observation and yearly population size estimate (**N**) obtained by line transect distance sampling. (**n** is used for estimation of fecundity rates, survival, and population growth rates based on Leslie matrix).

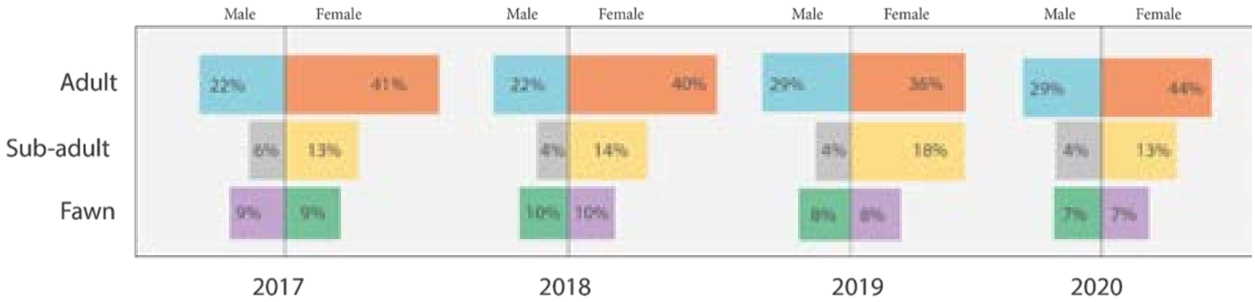

Figure 2. Age class pyramid depicting percentage age-sex composition among the years surveyed. (Values represent percentage composition).

Table 2. Year wise sex ratio for adult and sub-adult categories of Blackbuck.

Year	AM: AF	G^2 (p)	SAM: SAF	G^2 (p)
2017	1:1.9	3E-04 (0.97)	1:2.2	0.79 (0.31)
2018	1:1.8	0.1 (0.77)	1:3.5	**6.2 (0.01)**
2019	1:1.2	**19.6 (9E-06)**	1:4.2	**3.05 (0.02)**
2020	1:1.8	0.25 (0.61)	1:3.3	**6.4 (9E-03)**
Combined	1:1.9	3E-04 (0.97)	1:3.0	**0.88 (0.03)**

G^2 -test based on expected 1:1.9 ratio derived from the same study area during 1967 (Daniel, 1967). AM—adult male | AF—adult female | SAM—sub-adult male | SAF—sub-adult female | FA—fawn. Bold letters indicate significant values.

Table 3. Age-sex specific mortality rate (field observations) of Blackbuck during 2017–2020.

Age-sex category	Mean no. of individuals in the population, Q_x	No of deaths reported	No. of deaths in the age-sex class per year, D_x	Age-sex specific mortality rate (Q_x/D_x)
*FAF	69	28	2.3	10.1
SAF	83	9	2.3	2.7
AF	291	29	7.3	2.5
*FAM	69	28	2.3	10.1
SAM	33	6	1.5	4.6
AM	174	13	3.3	1.9

* FAF: represents fawn female and FAM represents: fawn male. Fawn were difficult to sex and thus assumed, as sex ratio at birth is equal. AM—adult male | AF—adult female | SAM—sub-adult male | SAF —sub-adult female.

significantly from the expected 1:1.9 ratio. However, for the year 2019 we found a significant deviation. Similarly, for the subadult categories, in 2017 there was no significant deviation from the expected ratio. While for 2018, 2019, and 2020 and ratio for the combined years were highly female biased, thus alternately deviates from the expected ratio. Table 2 provide sex ratio estimates for the years sampled.

Fecundity and survival

Natality rates could not be determined as it is challenging due to the behavior of newborn fawns, which involve lying down and concealing themselves in bushes alongside their mothers. It takes the newborn fawns and their mothers a few weeks to month to start following the rest of the herds. However, age-specific differences in fecundity were evident from the age sex composition. The fecundity and survival rates were estimated for constructing Leslie matrix, fecundity was highest in 2018 (F = 0.45) and overall mean for the years sampled was (F = 0.44), fecundity did not vary significantly among the years (X^2 = 8.8, p = 0.9). The survival rates were 0.75 for composite adult female class, 0.57 for female fawns and 0.37 for sub-adult females (Year wise and mean fecundity rate tabulated in S-Table 2; fecundity and survival rates given in Leslie matrix in S-Table 3).

Mortality

Age sex specific mortality from dead carcass counts on females was 2.7% per annum for the SAF and 2.5 for the AF category. Similarly, 4.6 % and 1.9 % were attributed to male classes, SAM and AM respectively. For each of the fawn category, using census data and carcass, mortality rate of 20% was estimated (FAF = 10%; FAM = 10%) (Table 3).

Population change (or growth)

From the female-based Leslie matrix model, the finite rate of population change (λ) was 0.97 representing a declining trend of population during the survey years. It was converted into instantaneous growth rate, (r = -0.025) required for age frequency correction in the subsequent life tables based on mortality. Stable age distribution (SAD) for the age classes were FAF = 0.16, SAF = 0.19, and AF = 0.62, and reproductive values (R_v) were FAF = 1, SAF = 1.08, and AF = 2.90. (Vital rates and life history parameters given in Table 4). Leslie matrix given in S-Table 3.

Table 4. Stable age distribution, reproductive values and growth rates derived from Leslie matrix and life history measures (Net reproductive rate, mean generation time, intrinsic rate of increase) derived from life table based on female mortality for the Blackbuck population.

Growth parameters	FAF	SAF	AF
Stable age distribution	0.16	0.19	0.62
Reproductive value	1	1.08	2.90
Finite growth rate, λ	0.97		
Instantaneous growth rate, r	-0.025		
Net reproductive rate, R_0	3.28		
Mean generation time, G	4.75		
Intrinsic rate of increase, r^m	0.24		

AF—adult female | SAF—sub-adult female | FAF—female fawn.

Based on reproductive rates estimated in our study through life tables (S-Table 4), the net reproductive rate (R_0) was estimated to be 3.28 per generation (Table 4) defined as the mean number of female offspring produced per female over her lifetime, contrasted with a rather low value of mean generation time (G) was 4.75 years. The intrinsic (or instantaneous) rate of population increase r^m was 0.24.

DISCUSSION

Population size

Point Calimere had over 2,300 individuals by 1995, but by 2017–2020 the population had dropped to 700–720 individuals presently as shown by this study. Point Calimere has a larger Blackbuck population than the other three remnant populations of Tamil Nadu: (1) Guindy National Park, Chennai, with 60 individuals (Annual census 2018, 2019 using line-transect distance sampling), (2) Sathyamangalam Tiger Reserve (Moyar Valley) with 600 individuals, and (3) Vallanadu Blackbuck Sanctuary, Tuticorin, with an average of with an average of 148 individuals (using line-transect distance sampling; Baskaran et al. 2020). In Velavadar, Gujrat about 400 Blackbucks were present when the preserve was established in 1969. After a decade, in 1976, the population peaked at around 2,500, and since then it has steadily declined to its current low of around 1,400 (Jhala & Isvaran 2016). In Karnataka, Blackbuck populations are still thriving only in a handful of remote locations. There are approximately 2,000 in the Ranebennur Blackbuck Sanctuary, 500 in the Jayamangali Blackbuck Conservation Reserve, and 800 in the Bidar area alone (Mohammed & Modse 2016). Odisha's Blackbuck population is concentrated in the Ganjam District in southern Odisha, with an estimated 43 Blackbucks per km^2 as of 2021 using a line transect distance sampling strategy (Patnaik 2021).

Age-sex composition

Our results show differences in sub-adult females were visible across the four years we looked at, but there were no statistically significant differences between the other age-sex groups. Although the proportion of fawns and subadult females decreased significantly over the course of the study, no significant trend emerged among other age-sex groups overall. Low recruitment rates into the population, as indicated by long-term trends or consistently low proportions at the young age classes, would lead to a decline in population size and persistence probability (Eberhardt & Breiwick 2012).

Sex ratio

The sex ratio at Point Calimere was 1:1.9, decades ago (Daniel 1967). The current study shows that this ratio has not changed significantly from the expected in the year(s) surveyed. This is the case until 2019, when we discover a significant deviation in adult category. Similar to the adult categories, there was no significant deviation from the expected ratio for the sub-adult categories in 2017. But from 2018–2020 and combined year ratios were much heavily skewed toward females.

Similarly in other areas as reported, Sathyamangalam Tiger Reserve shows female biased sex ratio, but the ratio is equal at Guindy indicating it did not fit into the expected level and shows deviation from the polygynous ratio (Baskaran et al. 2020).

In Blackbuck, males tend to be solitary; sub-adults tend to leave their mothers shortly after being weaned (Mungal 1978). Antelopes, due to their increased exposure to predators when exhibiting territoriality including intrasexual combat for mates, males are likely to have a higher mortality rate than females, as expected in polygynous mating system (Estes 2012). Males also emerge to range more widely than females. Also, sub-adult males, subordinate to adult males are treated agonistically until they disperse, mate competition provides the best explanation for male dispersal. Subsequently, a few adult males move into areas where the females are living and begin protecting territories (Walther et al. 1983). Adult males have a negligible effect on population shifts in any given population or site, population swings and long-term steadiness both result from shifts in the proportion of females in a population (Nunney 1991, 1993).

In mammals, females tend to outnumber males in the adult population (Emmel 1976). Any disparity from a gender balance of 50:50 points to male migration or mortality rates being higher than female ones. The males' tendency to disperse and the polygynous mating system in the Indian Blackbuck are both factors in the species' increasingly female-biased sex ratio and patterns. Results show a female preponderance in the species' sex ratio, and similar patterns were reported in studies of polygynous large herbivores (Graf & Nichols 1966; Schaller 1967; Dinerstein 1980; Johnsingh 1983; Karanth & Sunquist 1992; Khan et al. 1995; Sankar & Acharya 2004). Further, variation in sex ratio is both a cause and a consequence of sex- specific reproductive strategies, and these inter-relationships is reported to shape species-typical types of social organization, opportunities for different forms of paternal care.

Fecundity, survival and mortality

Despite the high female mortality caused by the Gajah cyclone at the end of 2018, we discovered that fecundity rates weren't lower in 2019 and is comparable to the other years surveyed. Since newborn fawns do not immediately join social groups, instead lie alone for the first few months of their lives (Mungall 1991), natality rates could not be determined (Jhala 1991). The demographic breakdown of the age groups and sexes, however, made age-dependent differences in fecundity obvious. Due to the interplay between fecundity and survival rates, fecundity alone may not be indicative of the direction or magnitude of changes in population size (Brongo et al. 2005). This suggests that estimates of both survival and fertility may be needed to better understand population dynamics (Sorensen & Powell 1998). Our findings showed that adult females had the highest survival rate, followed by female fawns, and then subadult females.

Mortality rate estimates for adult and subadult classes showed a higher mortality for the composite female class, however male subadult class showed much higher as a single age sex group. For the fawn category, using census data and carcass, mortality rate of 20% was estimated attributing 10% for each of the sex classes. The high rate of decomposition and the speed with which predators consume fawn remains make the possibility of a mortality incidences among fawns extremely hard to record relative to the older age classes (Indra et al. 2022).

Blackbuck population breed seasonally at Point Calimere, and the timing of breeding coincides with that of the population in Guindy National Park during September and October, both the areas showed a fawning peak between January and March, and a gap between April and August (Sathishkumar, forester at PCWS pers. comm. April/2018). They also breed seasonally in the Sathyamangalam Tiger Reserve, but there they have a birth peak in November. This disparity could be caused by rainfall patterns having two peaks during May and October in Sathyamangalam, which results in different plant growth patterns and an altered timing in the availability of food (Baskaran et al. 2020). Birth at captive population at Vandalur Zoo, Chennai, showed a peak between January and March, and a gap between April and August (pers. comm: Vandaloor Zoo Vet. Dr Boon Alvin 8/12/2018). Blackbuck at Valanadu Wildlife Sanctuary, Tootukodi, had a birth peak between October–December, which was the same as found at Sathyamangalam (Baskaran et al. 2020). Records of fawn seen at Point Calimere even indicated that some were born throughout the year (as per pers. comm: Mr S. Sathishkumar, Forester, Vedaranyam Forest Range, April/2018), but cull data indicated that the majority were seasonal (Baskaran et al. 2020). Similarly, in Velavadar, Blackbuck population is reported to exhibit two calving peaks: one after the monsoon (September) and one before the nutritionally stressed summer (March–April) (Jhala & Isvaran 2016).

In most large herbivores, the survival of fawns is generally low and varies over time in response to a wide range of proximal factors (Gaillard et al. 2000). While predation on and starvation of neonate fawns are reported to be major sources of mortality, at Point Calimere, feeding conditions are good with peak forage availability during the peak breeding and fawning time (Baskaran et al. 2020). This can probably explain proximate cause of mortality is not starvation. The Golden Jackal, the only known predator at Point Calimere, has been seen stalking fawns as they move with their mothers, usually they hide in halophytic bush *Sueda monioca* and given a chance, they attack on isolated mothers and their young (as per pers. comm: Mr S. Sathishkumar, Forester, Vedaranyam Forest Range, April/2018).

Population change (or growth)

Analysis using life tables assumes a closed population and this assumption is valid with group living and territorial animals (such as Blackbuck) (Skalski 2010).

With a finite rate of population change (λ) at 0.97, the female-based Leslie matrix model indicates a downward trend in population during the survey years. The negative instantaneous growth rate (r = -0.025) between the 2017 and 2020 periods was brought about primarily through reduced adult survival and fawn recruitment suggested the population was declining.

These analyses have created a representation of Blackbuck demography that depicts a population that contains 62% adult females and approximately 16–19% fawn female and subadults. It can be noted that our observed female age class distribution is not very dissimilar to the stable age distribution that we have predicted from our Lessie matrix, and hence, we can conclude that the population has been growing at a relatively constant and lower rate for some time, even the population has been affected by the 2018 Gajah Cyclone. Further, it is important to keep in mind that there may be more adults than fawns because adults typically stay in this age class for several years, whereas younger age classes typically only stay in their respective age classes for one or two years. Typically, when a growing population has a higher value of adult-stable age or stage distribution, its age structure changes (Gaillard et al. 1998, 2000) leading to an increase in the average age of adult females and so in the next few years, it is likely to obtain a greater adult mortality (Festa-Bianchet et al. 2003).

Similarly, age specific reproductive value (r_v) estimated for the population shows female fawns and sub-adult exhibiting r_v around 1, while the adults showed r_v around 3. This is a standard measure of the expected contribution of an individual in each state to the future population (Fisher 1930). Reproductive value initially increases with age, because each pre-reproductive year that an individual survives increases the probability that it will survive to reproductive age. r_v usually peaks near the age of first reproduction as the individual has its entire reproductive span yet to come.

The best parameter to describe and evaluate the growth of a population of a species to environmental conditions is the intrinsic rate of natural increase (r^m), which we obtained for the Blackbuck population as 0.24, using life tables. This value was close to, and somewhat less than zero, suggesting a population decline (Skalski 2006). A limited number of studies have highlighted population growth in terms of life table parameters, and there is a paucity of information on r_m-values for Blackbuck and other antelopes in India. A major barrier to using life tables is the large sample size required, also in many instances, individuals must be followed from birth to death, which can be challenging (Kajin et al. 2008).

Based on reproductive rates estimated in our study through life tables, the net reproductive rate (R_0) was estimated as low as 3.28 offspring per generation for a population, this value can be compared with another declining population of Blackbuck at Velavadar Wildlife Sanctuary, where Jhala (1991) found a similar trend with 3.2 offspring per generation. Further R_0 contrasted with a rather longer mean generation time (G) as 4.7 years (5.3 years: in Jhala 1991). Ungulates even if they are subjected to none or least predation reveal an increase in generation time and a population decline, because the low survival is not compensated by reproduction or recruitment rates and it is suggested that with moderate hunting pressure, particularly in the absence of large predators, ungulate populations display a colonizing demographic regime, characterized by high recruitment, a young female age structure, few senescent individuals, and shortened generation times (Crampe et al. 2006; Nilsen et al. 2009). At Point Calimere alternate pattern emerges, emphasizing the existence of factors such as effect of invasives, competition or other intrinsic socio-ecological determinants likely to reduce the population of Blackbuck (Baskaran et al. 2016, 2020; Arandhara et al. 2020, 2021). Earlier, Baskaran et al. (2016) reported possible effects of decline of this native species in the presence of invasive species like the feral horse in the community, for a long run and Arandhara et al. (2021a). marks the effect of invasive *P. juliflora* on the distribution ecology of Blackbuck in the sanctuary. Consistent with our results, Sophiya (2020) and Arandhara (pers. obs. March/2021) pointed out that limiting the number of vehicles and visitors to the park, as well as establishing specific visiting hours and zones, would benefit mating behavior, reproduction, and ultimately the viability of the Blackbuck population.

Conclusion and management recommendations

Our research adds to the basic understanding of these demographic attributes for large herbivores, establishing a baseline of data on the species, shedding light on life-history implications that can be expected for large herbivores in similar environments where similar conditions prevail.

To better manage a polygamous social species, like the Blackbuck, it's important to understand the social preferences, survival and lifetime reproductive success. The following management recommendation is made:

(i) Management of grasslands is essential to avoid invasion of alien woody plant. Invasion of *Prosopis* which is modifying the natural habitats, which suggest giving it higher priority. (ii) Blackbuck is a diurnal species, and the visitors time coincides with peak activity hours of Blackbuck, influencing the social dynamics of the

Blackbuck herds. Anthropogenic concentrations can alter mammals' foraging behavior (Ali 2005; Baskaran et. al. 2019). (iii) The feral-horse in the sanctuary, which competes with the native Blackbuck for resources and poses a serious threat, drives the Blackbuck away from suitable habitats. Thus, it is essential to humanely control its population so that it may not exclude the native species eventually.

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Supplementary Table 1. Density estimate of Blackbuck at Point Calimere Wildlife Sanctuary, Tamil Nadu, using line transect direct sighting method and distance sampling analysis for 2017–2020.

Parameters	2017	2018	2019	2020
No. of transects	8	8	8	8
Effort (l/km)	160	174	165	169
Number of group detection (n)	199	365	354	277
Key function model	Half Normal	Uniform	Half Normal	Half Normal
Key adjustment	Simple Polynomial	Cosine	Simple Polynomial	Simple Polynomial
Detection probability	0.31 ± 0.066	0.36 ± 0.087	0.29 ± 0.045	0.35 ± 0.157
Effective strip width (m)	205 ± 12.8	205 ± 12.8	205 ± 12.8	205 ± 12.8
Encounter rate of group/km (n/l)	1.44	1.52	1.35	1.74
Mean group size	2.9 ± 0.59	3.8 ± 0.66	4.2 ± 0.36	3.6 ± 0.47
Group density/km^2	8.0 ± 0.77	7.8 ± 0.62	8.5 ± 0.84	7.7 ± 0.93
Individual density/km^2	**27.6 ± 5.5**	**29.3± 4.3**	**28.7± 3.8**	**31± 8.4**
Population size for PCWLS	**716 ± 146.7**	**727± 162.9**	**711± 145.5**	**722± 168.9**

Supplementary Table 2. Year wise and mean fecundity rate of Blackbuck at Point Calimere Sanctuary, southern India.

Year	Fecundity	Mean fecundity	SE
2017	0.44		
2018	0.45	0.44	0.002
2019	0.44		

Supplementary Table 3. Leslie matrix for estimating population growth parameters of Blackbuck at Point Calimere Sanctuary, southern India.

Age-sex category	FAF	SAF	AF
FAF	0	0	0.44
SAF	0.58	0	0
AF	0	0.37	0.75

AF—adult female | SAF—sub-adult female | FAF—female fawn.

Supplementary Table 4. Mortality based life table analysis for female Blackbuck at Point Calimere Sanctuary, southern India.

Age(x)	f_x	f_x^1	f_x^2	$d_x e^{rx}$	l_x	m_x	$l_x(m_x)$	$l_x(m_x)x$
0	0	0	28	28	1.00	0.00	0.00	0.00
1	9	237	230	224	0.97	0.25	0.24	0.24
2	3	79	77	73	0.71	0.75	0.53	1.07
3	2	53	51	47	0.63	0.75	0.47	1.41
4	3	79	77	69	0.57	0.75	0.43	1.72
5	1	26	26	23	0.50	0.75	0.37	1.86
6	2	53	51	44	0.47	0.75	0.35	2.11
7	3	79	77	64	0.42	0.75	0.31	2.20
8	5	132	128	104	0.35	0.75	0.26	2.08
9	3	79	77	61	0.23	0.75	0.17	1.53
10	6	158	153	119	0.16	0.75	0.12	1.18
11	1.0	26.3	25.0	18.9	0.0	0.8	0.0	0.2
12	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0

fx—no. of dead carcass recorded | fx^1—hypothetical cohort of 1000 carcass of the age classes other than fawns | fx^2—hypothetical cohort including potential fawns and other age classes summing up to 1000 | dx e^{rx}—corrected age frequencies, here, coefficient (e^{rx}) corrects the age frequencies for bias caused by population growth (or decline) r—Lnλ | l_x— survivorship | m_x—fecundity schedules (Sinclair 1977; Krebs 2017).

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COMMUNICATION

Camera trap surveys reveal a wildlife haven: mammal communities in a tropical forest adjacent to a coal mining landscape in India

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Abstract: Having knowledge of the status and distribution of species in a specific geographic area is crucial for creating efficient conservation strategies. In this study, we evaluated the abundance and diversity of medium- to large-sized mammals in a tropical forest in India that has been adjacent to a coal mining landscape. Using camera traps between June and December 2018, we recorded 27 mammal species over 3,432 trap-nights in 81 camera trap stations in the study area. The photo-captured species included Tiger *Panthera tigris*, Leopard *P. pardus*, Sloth Bear *Melursus ursinus*, Asian Elephant *Elephas maximus*, Gaur *Bos gaurus*, Indian Pangolin *Manis crassicaudata*, and Four-horned Antelope *Tetracerus quadricornis*. Wild Boar *Sus scrofa* was found to be the most frequently photo-captured and widespread species. Our study provides data on the species inventory and the relative abundance of species in the area, highlighting its significance for mammal conservation. It emphasizes the need for effective management strategies to protect the remaining forest fragments around mining or highly operated areas having a high diversity of mammals.

Keywords: Occurrence, Odisha, *Panthera tigris*, population, relative abundance index, Sundargarh Forest Division, threatened species.

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Author contributions: NCP—developed the study concept, field data collection, and manuscript writing; BPR—conducted field survey, camera trapping and provided feedback to the final manuscript, HSP- Analysed the data and manuscript writing, AKM—developed the study concept, provided feedback to the final manuscript and supervised the project. All authors contributed to the article and approved the submitted version.

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INTRODUCTION

Mammals play a crucial role in the functioning of forest ecosystems. They interact with other biotic and abiotic components of the forest, influencing nutrient cycling, seed dispersal, and plant growth (Lacher et al. 2019). Mammals can also act as apex predators, regulating the populations and behavior of their prey, which can impact the structure and composition of the forest community (Ripple et al. 2014). Despite their vital role in forest ecosystems, they face a multitude of threats that can significantly impact their populations. Habitat destruction and fragmentation due to human activities such as deforestation, mining, and urbanization are some of the most significant threats to mammal communities in the world (Ripple et al. 2014, 2015; Nayak et al. 2020). Additionally, overhunting and poaching for their meat, hides, or other body parts are leading to a decline in mammal populations in most parts of the world (Brodie et al. 2009; Ripple et al. 2016; Rija et al. 2020). Therefore, it is essential to monitor the presence of mammal species in their habitat, as this is critical for the development of effective conservation management strategies (Nichols & Williams 2006).

Several important tools are available for monitoring mammal populations including camera trap, DNA analysis, radio telemetry, acoustic monitoring, satellite tracking, and transect surveys, which provide valuable data on their distribution, abundance, movement, and behavior (Buckland et al. 2023). However, camera traps are increasingly widely used tools for monitoring the mammal populations as they provide non-invasive and accurate data on their presence, behavior, and abundance (O'Connell et al. 2010; Forrester et al. 2016). In India, several camera trap studies have been conducted to assess mammal diversity in various ecosystems (Sathyakumar et al. 2011; Palei et al. 2016; Singh & Macdonald 2017; Lahkar et al. 2018; Rege et al. 2020; Ahmed et al. 2021; Chakraborty et al. 2021; Pal et al. 2021). Camera trap studies have the potential to explore not only species inventories and diversity of mammals but also to examine population size and density (Karanth 1995; Jhala et al. 2008; Singh & Macdonald 2017), demographic structure (Gardner et al. 2010; Harmsen et al. 2017), habitat utilization (Ramesh et al. 2012; Srivathsa et al. 2017), as well as spatio-temporal activity patterns (Ramesh et al. 2012; Palei et al. 2021).

As one of the mega-biodiverse countries, India is home to ~427 extant mammal species, representing about 8% of the world's mammal diversity (Srinivasulu 2018). However, large-scale modifications due to the growing human population and rapid economic growth have transformed the natural habitats into irregular mosaics among human-dominated spaces. The central Indian landscape with rich biodiversity, is currently facing significant habitat loss and fragmentation. This region has experienced rapid environmental changes due to the expansion of mining and agricultural activities since the 18th century (Soni 2020). The wildlife in these fragmented areas outside protected areas is relatively unexplored and yet important for conservation. Several studies have revealed that these remaining forest fragments contain high diversity of mammals, including threatened species (Rege et al. 2020; Ahmed et al. 2021; Chakraborty et al. 2021). Therefore, understanding the conservation status of mammal communities in these areas is crucial for conservation management strategies.

In this study, we used camera-trap surveys to study the presence of large- and medium-sized mammals on the northwestern periphery of Odisha State. We focused in a multiuse forest landscape of Sundargarh forest division with a strong presence of human and mining activities in the surrounding and inside forest. Our aim was to create a species inventory and evaluate the relative abundance of species to determine the potential significance of this area for conservation purposes.

MATERIAL AND METHODS

Study area

The study area covers an area of 450 km^2 and is located between 21.7752–22.0603 ^{0}N & 83.5445–83.8490 ^{0}E (Figure 1). It is situated in the southern part of the Sundargarh Forest Division of Odisha State, India, and includes reserved forests (RF) and protected forests (PF), such as Dhanubaunsha RF, Garjanpahar RF, Chhengapahar RF, Garjanjor RF, Rohini RF, Barghumra RF, Kanthidungri PF, and Kharudaldali PF. The western part of the study area is connected to Chhattisgarh State. The vegetation of the area is represented by tropical dry deciduous, northern tropical dry deciduous and northern dry mixed deciduous forest (Champion & Seth 1968). The mean minimum and maximum temperature varies 6–20 °C in January and 35–45 °C in May. The mean annual rainfall is 1,100–1,500 mm during the monsoon between June and September. Most villagers residing in the forest fringes are tribal, and their activities inside the forest are grazing livestock and collection of forest products (e.g., fodder for livestock, non-timber forest produce, and fuel wood). The major land-use that have been recorded in this area are forests, agriculture, habitations,

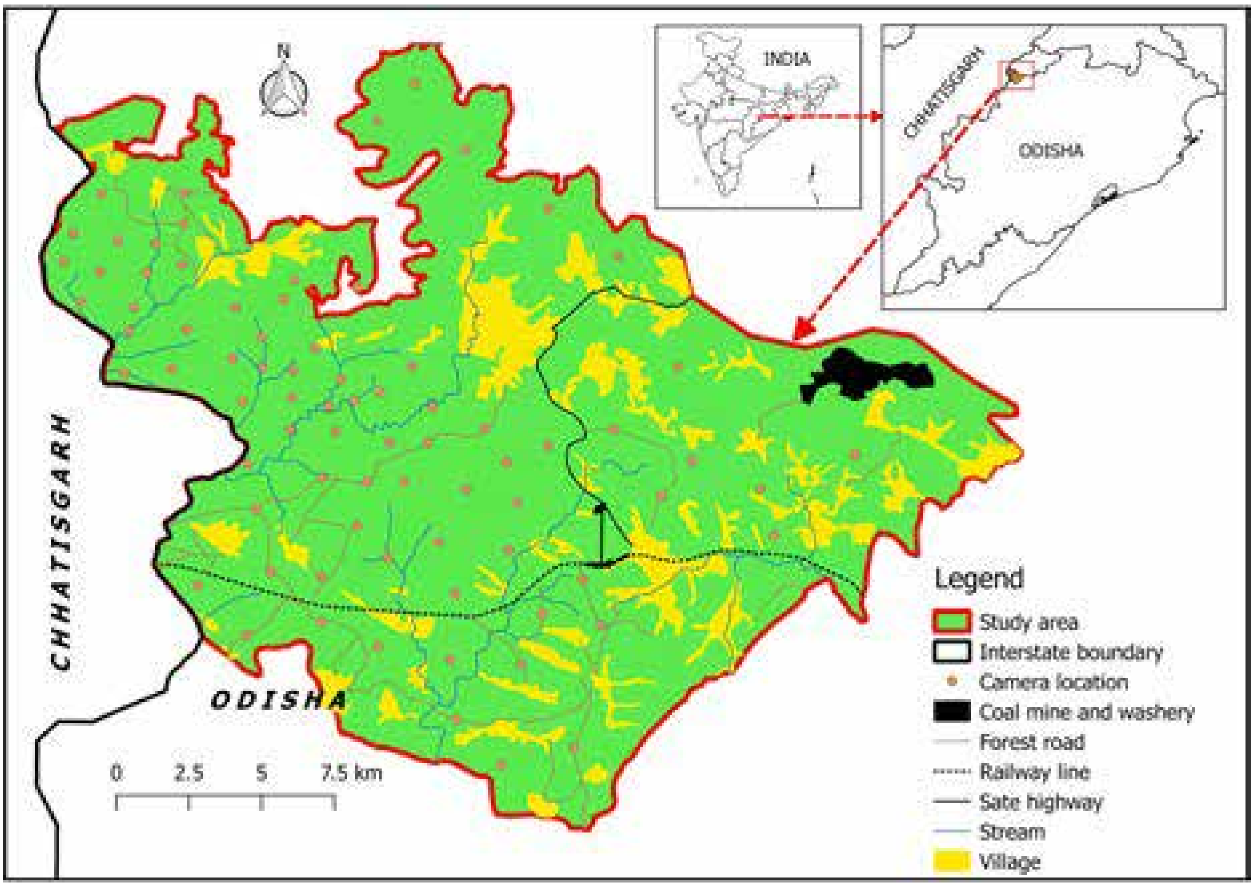

Figure 1. Study area and location of camera traps in the Sundargarh Forest Division, Odisha State, India.

waterbodies, road and railway lines, and open coal mining area.

Camera trapping

We surveyed mammals using camera traps during June–December 2018, at 81 camera trap stations in the study area. At each station, we collected data on geographical coordinates and altitude using a GPS. Camera-trap stations consisted of one camera trap, strategically positioned along trails, roads, or river banks in order to optimize the chances of capturing large- and medium-sized mammals, which have a tendency to move along linear features (Rasphone et al. 2019; Ouboter et al. 2021; Palei et al. 2021; Widodo et al. 2022). The mean distance between neighboring cameras was 1.64 ± SD 0.85 km, with placement carefully planned to ensure maximal geographical coverage. We used automated motion-triggered digital camera-traps (Cuddeback Model C1; Non-Typical, Inc., Green Bay, WI), mounted approximately 30–40 cm above the ground. The cameras were programmed to take high sensitivity photographs, with a 2 s interval between consecutive images. We checked camera traps every 15 days to replace batteries and to clear understory growth, reducing the risk of false triggers and vegetation obstructing the photographs. We aimed to leave camera traps in the forest for the 45 days, but due to work schedule conflicts, cameras were often picked up earlier or later in some locations.

Data analysis

Each photograph was manually checked to identify the species. Date, time and temperature were noted for each identified species. To avoid pseudo replication, animal detections were treated as separate events if they occurred more than 30 min after the previous photographs, unless individuals were distinguishable by unique pelage patterns, colors, or different sex/age categories (O'Brien et al. 2003). Multiple individuals of the same species in one photograph were counted as a single observation. For each species, we calculated the relative abundance index (RAI) by dividing the number of independent events by the number of trap-nights and then multiplying by 100 (O'Brien et al. 2003). We determined the naïve occupancy for each species by

Image 1. Camera trap images of threatened mammals recorded in the study area of Sundargarh Forest Division, Odisha, India: a—Tiger *Panthera tigris* | b—Leopard *Panthera pardus* | c—Sloth Bear *Melursus ursinus* | d—Asian Elephant *Elephas maximus* | e—Gaur *Bos gaurus* | f—Four-horned Antelope *Tetracerus quadricornis* | g—Indian Pangolin *Manis crassicaudata*.

dividing the total number of sites where the species was trapped by the overall number of sites. To evaluate the sampling effort, a species accumulation curve was plotted using Vegan package in R 4.2.2 (Gotelli & Colwell 2001).

RESULTS

The total number of camera trap nights was 3,432 with a mean of 42 trap nights (SD ± 16.61) per camera trap station. Site-specific species accumulation curves appeared to be asymptotic, suggesting that sampling effort was sufficient (Figure 2). We recorded 27 species of mammals belonging to 17 families in eight orders (Table 1). Carnivora was the most diverse order with 14 species, followed by Artiodactyla with five, Rodentia with two, Primates with two, and all other orders with a single species each. Of the 27 species recorded, eight are threatened (four 'Endangered', four 'Vulnerable'), two are 'Near Threatened' and 17 are 'Least Concern' on the IUCN Red List (IUCN 2023).

The most abundant mammal in the study area was Wild Boar *Sus scrofa* (RAI = 7.34), followed by Indian Hare *Lepus nigricollis* (6.63), Four-horned Antelope *Tetracerus quadricornis* (4.14), Rhesus Macaque *Macaca mulatta* (3.67), Jungle Cat *Felis chaus* (3.36), and Bengal Sacred Langur *Semnopithecus entellus* (3.26) (Table 1, Figure 3). We observed large variations in naïve occupancy estimates for mammals in the study area (0.01–0.75). The highest naïve occupancy estimates were for Wild Boar (0.75), followed by Bengal Sacred Langur (0.59), Jungle Cat (0.47), Rhesus Macaque (0.45), Four-horned Antelope (0.43), and Leopard (0.40) (Table 1, Figure 4). Throughout the study area, four threatened species were regularly captured: the Asian Elephant (n = 50, in 19 locations), Four-horned Antelope (n = 142, in 29 locations), Sloth Bear (n = 61, in 32 locations), and Leopard (n = 61, in 33 locations) (Table 1).

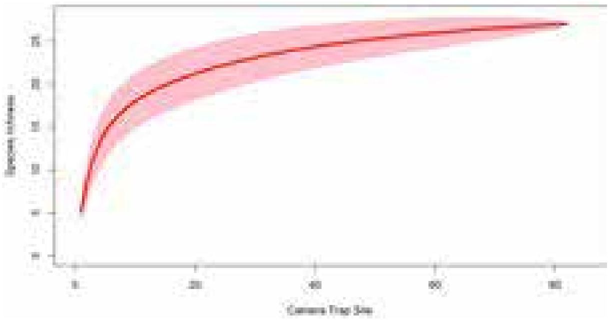

Figure 2. Randomized species accumulation curve based on the number of camera traps in the study area. Shaded area indicates the 95% CI.

DISCUSSION

Our study confirms that the study area is home to a diverse population of terrestrial mammals, including many important and threatened species such as Tiger,

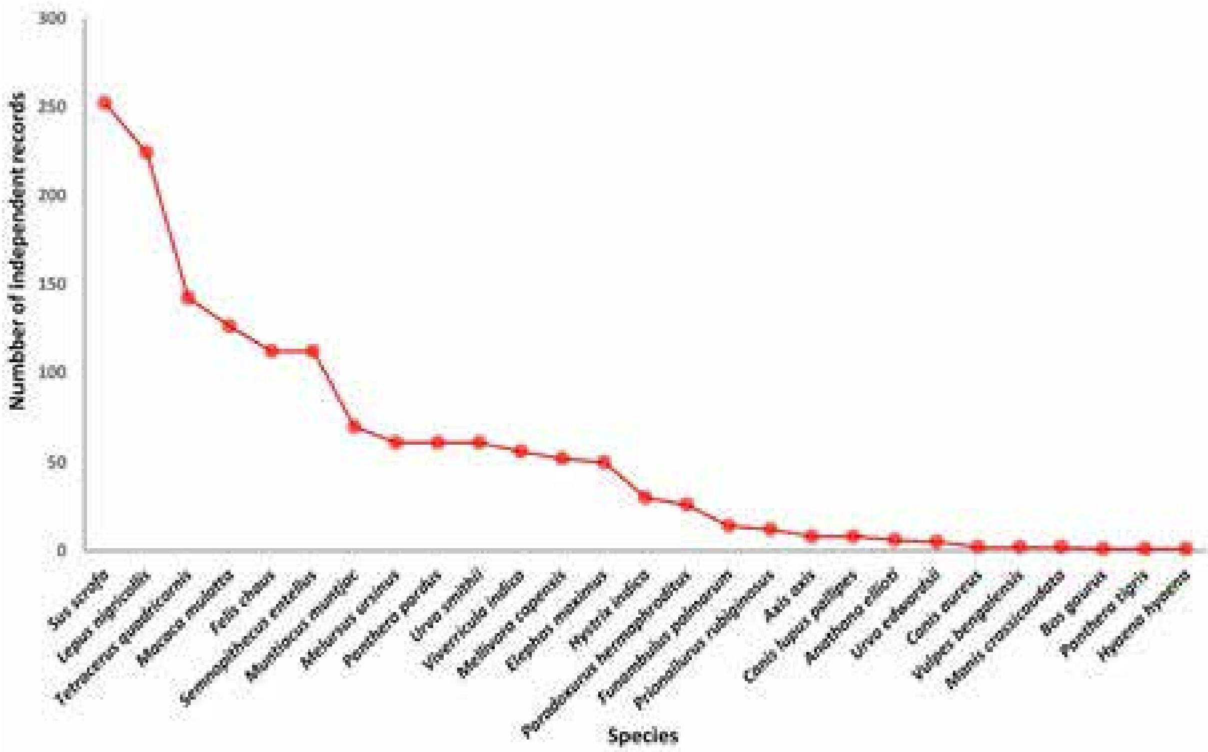

Figure 3. Capture frequency of mammals in the study area of Sundargarh Forest Division, Odisha, India.

Table 1. Relative Abundance Index (RAI) of Wildlife species and others captured photos.

	Species name	Scientific name	Food habit	IUCN Red List status	CT stations	Independent record	RAI	Naïve occupancy
	A. ORDER: ARTIODACTYLA							
	Family: Cervidae							
1	Barking Deer	*Muntiacus muntjac*	H	LC	21	70	2.04	0.25
2	Spotted Deer	*Axis axis*	H	LC	3	8	0.23	0.03
	Family: Suidae							
3	Wild Boar	*Sus scrofa*	H	LC	61	252	7.34	0.75
	Family: Bovidae							
4	Four-horned Antelope	*Tetracerus quadricornis*	H	VU	35	142	4.14	0.43
5	Gaur	*Bos gaurus*	H	VU	1	1	0.03	0.01
	B. ORDER: PROBOSCIDEA							
	Family: Elephantidae							
6	Asian Elephant	*Elephas maximus*	H	EN	19	50	1.46	0.23
	C. ORDER: CARNIVORA							
	Family: Ursidae							
7	Sloth Bear	*Melursus ursinus*	O	VU	32	61	1.77	0.39
	Family: Felidae							
8	Tiger	*Panthera tigris*	C	EN	1	1	0.03	0.01
9	Leopard	*Panthera pardus*	C	VU	33	61	1.78	0.40
10	Rusty-spotted Cat	*Prionailurus rubiginosus*	C	NT	3	12	0.35	0.03
11	Jungle Cat	*Felis chaus*	C	LC	38	112	3.36	0.47
	Family: Canidae							
12	Indian Wolf	*Canis lupus pallipes*	C	LC	6	8	0.23	0.07
13	Golden Jackal	*Canis aureus*	C	LC	1	2	0.06	0.01
14	Bengal Fox	*Vulpes bengalensis*	C	LC	1	2	0.06	0.01
	Family: Hyaenidae							
15	Striped Hyena	*Hyaena hyaena*	C	NT	1	1	0.03	0.01
	Family: Mustelidae							
16	Ratel	*Mellivora capensis*	C	LC	27	52	1.51	0.33
	Family: Viverridae							
17	Small Indian Civet	*Viverricula indica*	C	LC	30	56	1.63	0.37
18	Common Palm Civet	*Paradoxurus hermaphroditus*	O	LC	16	26	0.76	0.19
	Family: Herpestidae							
19	Ruddy Mongoose	*Urva smithii*	C	LC	6	61	1.78	0.07
20	Indian Grey Mongoose	*Urva edwardsii*	C	LC	4	5	0.15	0.05
	D. ORDER: PRIMATES							
	Family: Cercopithecidae							
21	Rhesus Macaque	*Macaca mulatta*	H	LC	37	126	3.67	0.45
22	Bengal Sacred Langur	*Semnopithecus entellus*	H	LC	48	112	3.26	0.59
	E. ORDER: PHOLIDOTA							
	Family: Manidae							
23	Indian Pangolin	*Manis crassicaudata*	I	EN	2	2	0.06	0.02
	F. ORDER: LAGOMORPHA							
	Family: Leporidae							
24	Indian Hare	*Lepus nigricollis*	H	LC	42	224	6.53	0.51

	Species name	Scientific name	Food habit	IUCN Red List status	CT stations	Independent record	RAI	Naïve occupancy
	G. ORDER: RODENTIA							
	Family: Hystricidae							
25	Indian Crested Porcupine	*Hystrix indica*	H	LC	20	30	0.87	0.24
	Family: Sciuridae							
26	Indian Palm Squirrel	*Funambulus palmarum*	H	LC	5	14	0.41	0.06
	H. ORDER: SCANDENTIA							
	Family: Tupaiidae							
27	Madras Treeshrew	*Anathana ellioti*	H	LC	4	6	0.17	0.05

RAI—Relative Abundance Index | CT—Camera Trap | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | C—Carnivore | H—Herbivore | I—Insectivore | O—Omnivore.

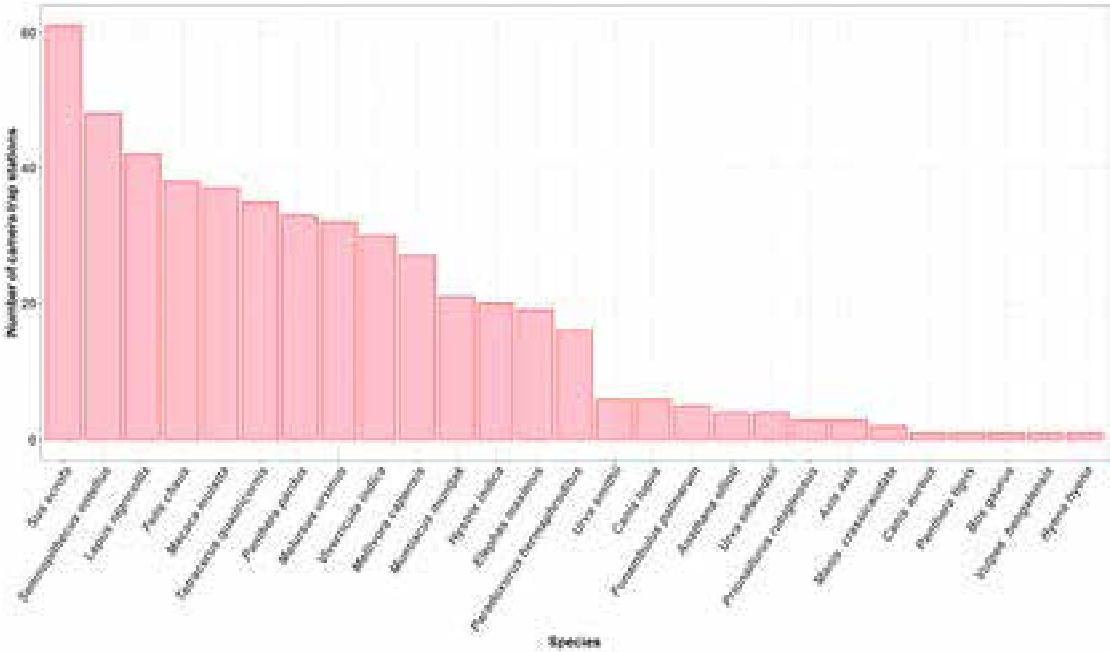

Figure 4. Mammal species recorded in camera stations in Sundargarh Forest Division, Odisha, India.

Leopard, Sloth Bear, Asian Elephant, Gaur, and Indian Pangolin. Our study area exhibits a high diversity of terrestrial mammals, which becomes evident when compared to camera trap studies conducted in other parts of India, e.g., 24 mammals over 6,413 trap-nights in 187 camera trap stations in Similipal Tiger Reserve, Odisha (Palei et al. 2016), 20 mammals over 916 trap-nights in 65 camera trap stations in Kuldiha Wildlife Sanctuary, Odisha (Debata & Swain 2018), 24 mammals in 52 camera traps over 660 trap-nights in the Bandhavgarh-Sanjay Corridor (Vaishnav et al. 2021), and 27 mammals in 123 camera trap locations over 3,250 trap-nights in Debrigarh Wildlife Sanctuary, Odisha (Palei et al. 2023).

While photographic capture rates can be a helpful indicator of relative abundance (Carbone et al. 2001), it may not be directly comparable between different species due to differences in detectability (Jennelle et al. 2002). As a result, we refrained from comparing relative abundance across species. However, despite its limitations, photographic rates can still yield valuable insights into comparing the relative abundance of specific species across various locations and identifying general patterns of species richness.

A major finding of our study is the detection of Tiger, Leopard, and Four-horned Antelope in the study area, as former one is classified as 'Endangered' and latter two as 'Vulnerable' by the IUCN Red List of Threatened

Species. In this region, information on the distribution of the Tiger is limited (Debata & Palei 2020). The presence of tigers in our study area is a positive indication of the forest's ecological richness and the region's potential for tiger conservation. The study area is connected to central Indian tiger landscape, which is home to a substantial population of tigers (Jhala et al. 2008). This connectivity provides opportunities for the long-term survival prospects of tigers in the region. Although leopards are widely distributed throughout the state, their vulnerability to poaching is a real concern across the state and the country (Mondol et al. 2015). In Odisha, the Four-horned Antelope is considered rare and was only reported 20 years ago from the Similipal Tiger Reserve (Singh & Swain 2003). The presence of these threatened species in this human dominated landscape emphasizes the need for regular monitoring of them and their habitat.

Our study shows widespread presence of Sloth Bears and Asian Elephants, which may result in an escalation of human-wildlife interactions. Sloth Bears are known for raiding crops and can become aggressive towards humans if they perceive a threat (Debata et al. 2017; Delgado et al. 2020), while Asian Elephants can cause significant damage to crops and property, and can also pose a serious threat to human life (Palei et al. 2017, 2019). Therefore, it is crucial to develop effective management strategies to mitigate human-wildlife negative interactions for the region.

Within the study area, a coal mine is present along with transportation networks that bisect the forest, including railways and roads. Additionally, there are proposed coal mine projects or expansions that have the potential to further degrade the forest (CIRTD & CPR 2020). Large mammals, such as Asian Elephants, Tigers, and Gaurs, are particularly vulnerable to these disturbances as they require large areas and are easily disrupted by human activities (Ripple et al. 2014, 2015). There have already been negative consequences, as evidenced by a female elephant being killed in a train accident within the study area in 2017. Therefore, regular evaluation of the mammal community in light of surrounding development activities would help to assess the effectiveness of measures taken to increase protection and restore habitats.

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COMMUNICATION

Observations of Gray Fox *Urocyon cinereoargenteus* (Schreber, 1775) (Mammalia: Carnivora: Canidae) denning behavior in New Hampshire, USA

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Abstract: Dens are important for mammals because they provide protection for dependent young from weather and predators. Gray Foxes *Urocyon cinereoargenteus* are an understudied mesocarnivore that range across North and Central America, and have limited information available on demographics and denning behaviors. We monitored a Gray Fox den in New Hampshire over the course of three years (2017–2020) to quantify behaviors and document visitation and activity patterns of Gray Foxes and other mammal species. We observed Gray Fox pairs intensively using the den during parts of the first and second years of the study. Across the 949 trap nights over which we monitored the den, use by adult Gray Foxes peaked in spring – coinciding with the pup-rearing season. During this time, the adults were diurnal with peaks in the afternoon, opposed to being crepuscular at other times of the year. We did not observe any puppies during the first breeding season, but during the second year we documented a puppy emerging from the den on 24 May 2018. All excursions by the puppy outside the den for the first five days were restricted to the immediate area near the den entrance and the puppy was always with an adult when outside the den. During the puppy's second solo excursion, however, we documented a Bobcat *Lynx rufus* pounce and kill the puppy, after which the adults abandoned the den. We also observed the common (squirrels and rabbits) and uncommon (a bat) prey items brought to the den, and the den being shared among multiple species. Our observations highlight the importance of dens for protecting young, and our observations of visitation and activity patterns, as well as common and uncommon prey, help inform our understanding of the denning behavior of Gray Foxes.

Keywords: Activity patterns, den, mammal, neonatal, predation, prey.

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INTRODUCTION

Dens are important for mammals as a means to protect the dependent young from weather and predators. Most canids primarily use dens (generally holes dug in the ground) for raising young, and while they may visit den sites throughout the year, activity often peaks from mid-winter to early summer (Egoscue 1956; Chesemore 1969; Uraguchi & Takahashi 1998). During this period, the pair bonds are often the strongest and the mating pair act as central place foragers, which exhibits itself as the pair often making foraging forays away from the den and returning with food (Nicholson et al. 1985; Way et al. 2001; Allen & Moll 2023). Behaviors at the den are often difficult to observe, and while there are many studies on canid den selection, there are fewer studies documenting behaviors at dens (but see Way et al. 2001; Elbroch & Allen 2013; Mukherjee et al. 2018).

Gray Foxes *Urocyon cinereoargenteus* are an understudied mesocarnivore that ranges across North and Central America (Allen et al. 2022), and has limited information available on demographics and denning behaviors (Allen et al. 2021). The breeding cycle is generally thought to be from January through April, with later dates in more northern areas (Sheldon 1949). The exact gestation period is unknown and is often estimated as the same 53 days as Red Foxes *Vulpes vulpes* (Sheldon 1949). Litter size ranges from one to six, with averages of three to four puppies (Sheldon 1949; Sullivan 1956; Wood 1958; Weston & Brisbin 2003; Glenn et al. 2009). While Gray Foxes were traditionally thought to be monogamous, more recent research shows that up to half of the litters exhibit multiple paternity (Glenn et al. 2009).

Gray Fox dens can be in all areas, including ground dens, cavities among rock piles or ledges, brush piles, under buildings, and hollow logs (Sullivan 1959; Nicholson et al. 1985). However, the use of dens appears to vary based on the stage of puppy rearing, with only underground dens used during the weaning period, but hollow logs used during whelping and nursing periods (Nicholson et al. 1985). Female movements are similarly restricted by rearing stage, with movements greatly reduced during whelping and nursing stages (Nicholson et al. 1985). Given that Gray Foxes are often associated with forested habitats (Allen et al. 2021, 2002), it is likely that den sites are often selected in forested areas similar to Red foxes (Uraguchi & Takahashi 1998). However, Gray Foxes prefer denning among denser cover and closer to water sources (Sullivan 1959).

We monitored a Gray Fox den in New Hampshire over three years to quantify behaviors and document visitation patterns of Gray Foxes and other species. We calculated the relative abundance for all species using the den and the relative abundance, temporal patterns, and duration of visits for Gray Fox adults and puppies. We also documented predation of a puppy and prey items brought to the den by adult Gray Foxes.

MATERIALS AND METHODS

Study Area

We monitored a Gray Fox den in a mixed forest area on private land in Strafford County, New Hampshire (43.114, -70.918). Common tree species surrounding the den site include Eastern White Pine *Pinus strobus*, Northern Red Oak *Quercus rubra*, Red Maple *Acer rubrum*, American Elm *Ulmus americana*, and Black Birch *Betula lenta*. The surrounding area is a low-density suburb consisting of generally wooded lots, with a number of adjacent undeveloped conservation properties owned by municipal, state, and non-profit landowners. Temperatures in the area reach wintertime lows below 0^0C and summertime highs above 25^0C. Rainfall is moderate and relatively consistent throughout the year, with monthly lows of approximately 70 mm in the winter and around 100 mm in the spring and fall, but overall precipitation is highest in the winter due to monthly snowfall that can exceed 300 mm. Mammal species in the area are typical of the northeastern USA, including Black Bears *Ursus americanus*, Bobcats *Lynx rufus*, Coyotes *Canis latrans*, Fishers *Pekania pennanti*, Raccoons *Procyon lotor*, Red Foxes, Striped Skunks *Mephitis mephitis*, Virginia Opossums *Didelphis virginiana*, White-tailed Deer *Odocoileus virginianus*, and Woodchucks *Marmota monax*.

Field Methods

We first sighted a Gray Fox traversing the property and entering the den in early February 2017, and again in early April 2017. Following the second sighting, we set up a camera trap to monitor the presence and activity of Gray Foxes and other species. We used a Browning Recon Force (Model no. BTC-7FHD; Birmingham, AL, USA) to record a burst of four images with two seconds between images when triggered, with a 1-minute delay between bursts. We ran the camera trap continuously from 13 April 2017, until 7 March 2020, with brief and infrequent gaps in coverage due to dead batteries. The camera trap was mounted on a nearby tree 55 cm off the ground and approximately 4.2 m from the den entrance.

The field of view was approximately 5 m wide by 2.5 m high, and centered on the den entrance.

We observed Gray Fox pairs intensively using the den during parts of the first and second years of the study, but not during the third year (after which we ended the study). The den was situated on a well-drained slope alongside a poorly drained and seasonally flooded gully adjacent to several residential properties. Near-surface and emergent granitic bedrock creates a variety of ledges, crevices, and other structures along the slope. We could only confirm one entrance to the den, although its interior structure is unknown and it is possible other entrances might exist along the rocky ledge.

Statistical Analyses

We used program R version 4.2.2 (R Core Team 2022) for all statistical analyses. We calculated relative abundance (RAB) on a monthly scale as:

RAB = visits / trap nights

to quantify the average number of visits per day for each species, as well as gray fox adults and puppies. We calculated the duration of visits to the nearest minute and calculated a monthly average.

We used kernel density estimation to quantify temporal activity patterns (Ridout & Linkie 2009). Our two comparisons were the overlap between adults and puppies during the period when the puppy was active outside of the den (24 May 2018 to 30 May 2018), and the overlap between adults during times when they were intensively using of the den (April and May during 2017 and 2018) versus their use during the rest of the year. We used the time each visit started as our values, after changing the time of each visit to radians that corresponded to sun time. We then used the 'overlap' package (Meredith & Ridout 2017) to fit the data to a circular kernel density. We estimated the activity among time periods from the kernel density distribution. For our first comparison, we used D [illegible] due to small sample sizes, and in the second comparison, used D [illegible].

RESULTS

Across the 949 trap nights we monitored the den, we documented 27,072 photos, representing 3,205 independent visits by animals. During the first year, the presumptive female (based on smaller size) was distinctive by having a thin, uneven, and light-colored coat with minimal characteristic markings. We observed the pair immediately and consistently following installation of the camera trap on 13 April 2017, through 26 May 2017 (Figure 1a). Thereafter, the Gray Foxes were observed only occasionally near the den entrance and presumably had vacated the den. We did not observe any puppies during the first breeding season.

After the den was vacated in May 2017, a pair of Gray Foxes began visiting and using the den periodically from October 2017 through March 2018, before taking up regular residence again in April 2018 (Figure 1a). Both animals had more typical coats and markings, suggesting that either the presumptive female from the first year had matured or regained health, or that one or both individuals were different from those that had used the den the previous spring.

During the second year of observation, we first documented a puppy emerging from the den on 24 May 2018. For the first five days, the movement of the puppy was restricted to the immediate area near the den entrance and the puppy was always with an adult when outside the den. We never documented more than one puppy, and we assume all observations were of the same individual. Overall, this encompassed a total of 27 visits with an average duration of 21.9 minutes per visit. The puppy was most active in the afternoons (Figure 2a), and during this time the activity of adults was nearly a perfect mirror for activity of the puppy (D [illegible] = 0.95).

On 29 May at 0451 h, the puppy made its first solo excursion outside of the den, spending less than one minute outside alone. On 30 May, the puppy emerged for its second solo excursion at 0215 h and explored around the den entrance until 0225 h, when we documented a Bobcat pounce and kill the puppy (Image 1). This was the first visit we documented by a Bobcat since 9 May 2017. But the Bobcat returned again twice on 30 May 2018 at 0253 h and 0322 h, both times appearing to search around the den, with follow up visit on 01 and 02 June 2018.

Overall, use of the den by adult Gray Foxes peaked in spring, coinciding with the breeding and pup-rearing season (Figure 1a). Use of the den became more frequent each year in November, but was substantially more frequent in April and May (Figure 1a). However, after Bobcat predation of the puppy in May 2018, there was little activity at the den, with a few visits in January, February, and March 2019 but no visits in any other months. During the two months that adult foxes were actively using the den (April and May), they were most active during the daytime, with peaks in the afternoon (Figure 2b). At other times of the year, the activity of adult Gray Foxes was strongly crepuscular.

We documented adults returning to the den with 51

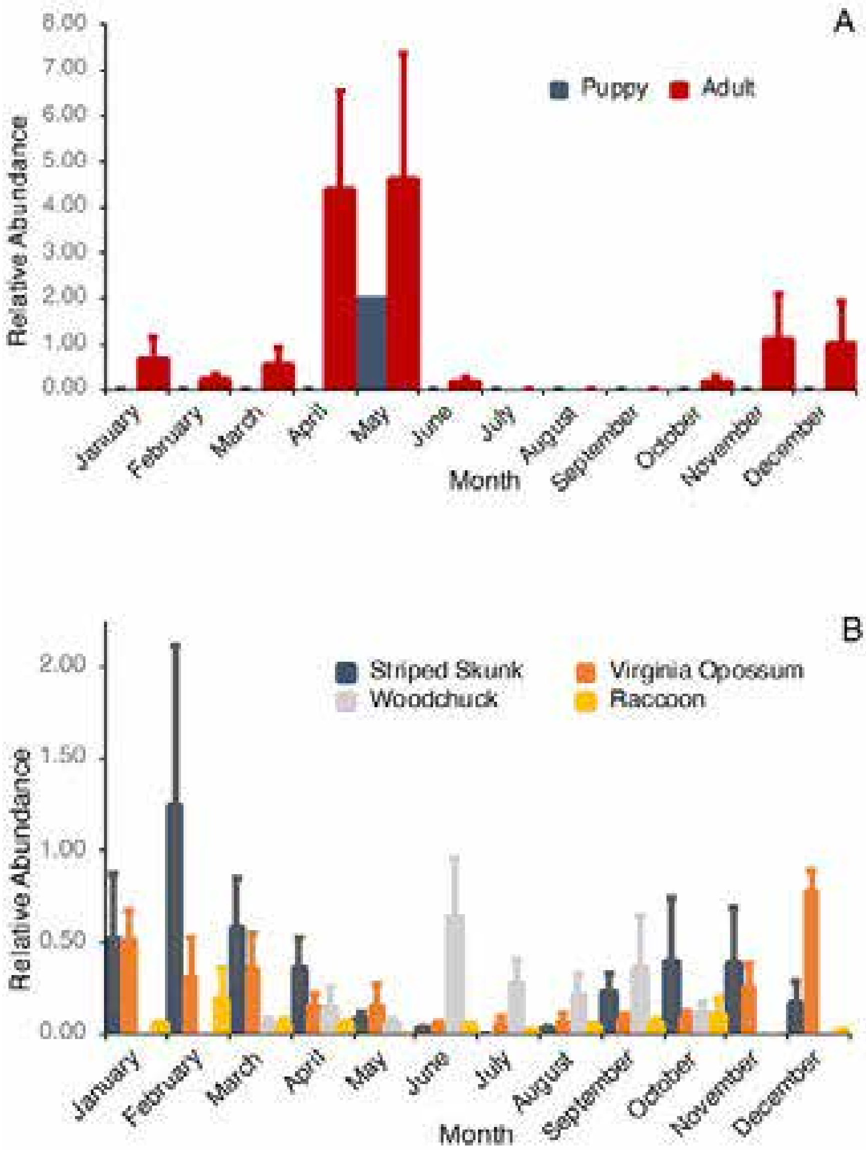

Figure 1. The relative abundance (visits per trap night) by month for: A—Gray Foxes (adults and puppy) | B—other species that also use the den (Raccoon, Striped Skunk, Virginia Opossum, and Woodchuck).

prey items. Most of the prey items (n = 35) were not identifiable in the photographs. The most common prey we could identify was Eastern Gray Squirrels *Sciurus carolinensis* (n = 12) followed by Eastern Cottontails *Sylvilagus floridanus* (n = 3). The other notable prey item that we observed was a bat of indeterminate species (Image 2).

Besides Gray Foxes (n = 1,029 visits), we documented visits by multiple species that also used the den, including Striped Skunks (n = 316), Virginia Opossums (n = 207), and Woodchucks (n = 140). Skunks and opossums used the den more frequently in the winter, presumably for protection from the weather, whereas Woodchucks more frequently used the den in summer and fall prior to hibernation (Figure 1b). Notably, we observed Gray Foxes, skunks, opossums, and Woodchucks using the den close in time to one another, reflecting den-sharing among these species. We also documented other carnivores near the den site including Domestic Dog *Canis lupus familiaris* (n = 51), Northern Racoon (n = 44), Domestic Cats *Felis catus* (n = 20), Bobcats (n = 14), Coyotes (n = 5), Red Foxes (n = 5), Long-tailed Weasels *Neogale frenata* (n = 2), and a Fisher (n = 1). We also documented other mammals, the most frequent of which included Eastern Gray Squirrels (n = 731), Eastern Chipmunks *Tamias striatus* (n = 454), and White-tailed Deer (n = 79).

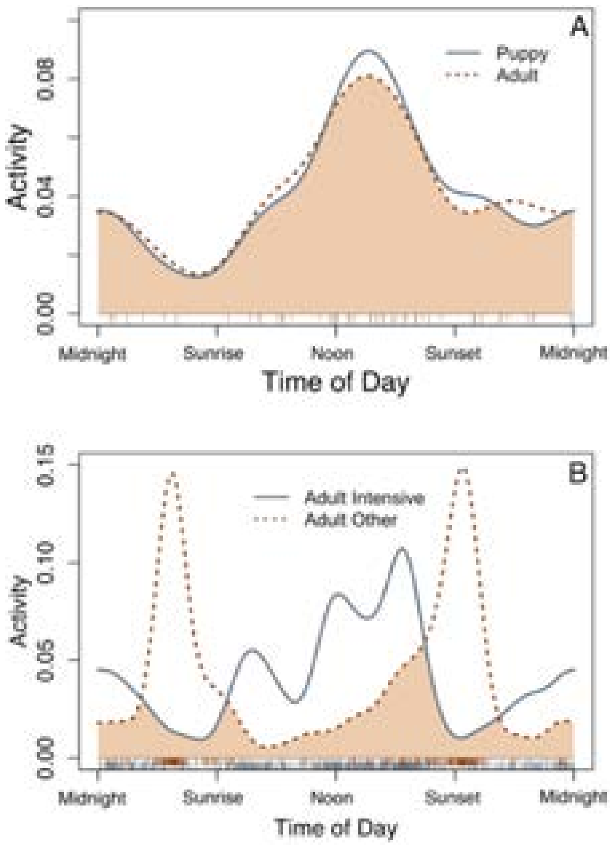

Figure 2. The activity patterns of gray foxes at the den site, adjusted to sun time. A—comparison of the activity of the puppy and adults in the period the puppy was active outside the den | B—comparison of the activity of adults during their intensive use of the den (April and May) and the rest of the year.

DISCUSSION

We documented Gray Foxes acting as central place foragers and using the den as their focal area of activity. The use of the den by Gray Foxes in the first and second year of monitoring peaked in April and May, which coincides with the birthing season. We first documented a puppy emerging from the den on 24 May in the second year, and this was approximately the same time the den was vacated during the previous year although we did not observe any puppies during the first year. This could have been due to the female being immature or ill (e.g., mange), the pair moving to a new birthing den, or the puppies dying in the den before emergence. After the puppy was killed by the Bobcat in the second year, the adults vacated the den and did not use it again the following year.

Our observations highlight the importance of using dens for protecting young. Initially the Gray Fox puppy was using the area outside of the den in the company of a parent, with the activity patterns of the parents mirroring that of the puppy. This protection is helpful because parents can signal danger to young (in which case young can retreat into the den) and also potentially fight off other predators. When puppies are outside of the den in the absence of parents, they are likely more prone to predation and the second time we observed the puppy by itself outside of the den it was killed by a Bobcat. The typical survival rates of juvenile Gray Foxes (0.34) are often half that of adults (0.77) (Farias et al. 2005), with predation being a common source of mortality for Gray Foxes. Predation is most often attributed to Coyotes (Weston & Brisbin 2003; Farias et al. 2005), although Bobcat predation has also been documented (Farias et al. 2005), along with legal harvest, vehicle collisions, and disease (see review in Allen et al. 2021). While Gray Foxes are well known for their ability to climb trees to escape predation, puppies are unlikely to be coordinated enough to climb trees, emphasizing the importance of the den for safety.

Adult Gray Foxes are thought to leave dens for short (~ one hour) hunting forays at crepuscular times to hunt for food (Nicholson 1985). Although we found that Gray Foxes were crepuscular at most times of year, they tended to be diurnal during times they were intensively using the den (Figure 2b). We did not distinguish between behaviors like sunning themselves outside of the den and hunting forays, and these behaviors may occur at different times of day. We did document adults frequently returning to the den with prey items, with larger prey (such as squirrels and cottontails) and distinctive prey (bats) easier to identify. The bat is notable because the scavenging of bats can lead to the transmission of rabies (Theimer et al. 2017) and bringing a bat back to the den increases risk for the entire family. It also raises the question of how the Gray Fox acquired the bat. Eight species of bats reside in New Hampshire, several of which roost primarily or opportunistically in trees where Gray Foxes may hunt, but Gray Foxes are also known to scavenge bats (Theimer et al. 2017). Young animals need large quantities of food, so parents likely bring whatever food is available back to the den. While Gray Foxes often focus on common prey (e.g., squirrels, small rodents, and rabbits), they have been documented bringing prey back to the den ranging from Banana Slugs *Ariolimax columbianus* to deer (Elbroch & Allen 2013).

In addition to our detailed observations of Gray Fox behavior, we also documented interspecific den-sharing among different combinations of Gray Foxes, Striped Skunks, Virginia Opossums, and Woodchucks.

Image 1. Documentation of Bobcat *Lynx rufus* predation on a Gray Fox puppy, during the puppy's second solo excursion outside of the den.

Image 2. Gray Fox returning to den with a bat, an uncommon prey species.

Den-sharing entails trade-offs between costs such as competition for space and increased pathogen exposure, and benefits such as information sharing and thermoregulation (Zeus et al. 2017). The balance of these trade-offs will vary among the species in question and might not be reciprocal. For example, Cape Ground

Squirrels *Xerus inauris*, Suricates *Suricata suricatta*, and Yellow Mongooses *Cynictis pencillatus* commonly share burrows in Namibia (Waterman & Roth 2007). Ground Squirrels benefit from warning vocalizations by Suricates, but are at risk of predation on their juveniles by Yellow Mongooses. Both Suricates and Yellow Mongooses benefit from aggressive predator mobbing behavior by Ground Squirrels. Bats can preferentially select roosts occupied by conspecifics or heterospecifics due to the information conveyed about habitat quality (Zeus et al. 2017). However, den-sharing among different species of Spiny Lobsters *Panulirus* spp. and Moray Eels *Gymnothorax* spp. in shallow, tropical marine systems might be driven by habitat limitation rather than any clear costs or benefits of cohabitation (Lozano-Álvarez et al. 2007; Lozano-Álvarez et al. 2010). The extent to which den-sharing among the species observed in this study represents costs-benefit trade-offs or habitat limitation (i.e., lack of ideal dens) is unclear but may affect the activity and conservation of these species.

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COMMUNICATION

Historical and contemporary perpetuation of assumed occurrence reports of two species of bats in Rajasthan, India

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Abstract: *Hesperoptenus tickelli* (Blyth, 1851) and *Rhinopoma muscatellum* Thomas, 1903 have been reported to occur in Rajasthan. Yet, there has been no empirical evidence of the occurrence of these bat species in the state. A comprehensive literature review reveals that the inclusion of these bats in accounts of chiropteran species in Rajasthan is due to the historical and contemporary perpetuation of assumed occurrence reports.

Keywords: Chiroptera, empirical evidence, *Hesperoptenus tickelli,* inclusion, literature review, *Rhinopoma muscatellum.*

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Author details: Dr. Dharmendra Khandal Phd, has served as conservation biologist with Tiger Watch since 2003. His work with Tiger Watch has involved pioneering ground breaking initiatives in proactive anti-poaching, the monitoring of wildlife & scientific research. He has also forged new frontiers in the world of community based conservation through the Village Wildlife Volunteer program in the Ranthambhore Tiger Reserve. He is also the co-author of Unexplored Ranthambhore, a first of its kind book on the canids and striped hyena in Ranthambhore. Ishan Dhar became associated with Tiger Watch since 2015 and has actively participated in Tiger Watch conservation interventions ever since. He has also served on Tiger Watch's Board of Directors since 2017. The youngest individual to do so. He has co-authored a book on the Village Wildlife Volunteer program titled Wildlife Warriors, along with multiple research articles in journals, the electronic and print media. Dr. S. Talmale PhD, is a taxonomist working on Indian small mammals and (Insecta) Odonata with several research papers and books to his credit. He is currently affiliated with the Zoological Survey of India.

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INTRODUCTION

The state of Rajasthan in northwestern India has an established history of exploration and study when it comes to the animal group Chiroptera. The observers in the early period of exploration were not necessarily systematic, and some chiropteran species recorded during this period in Blanford (1888–91), Ryley (1914), and Wroughton (1918) were never documented in the state afterwards. Post-independence, there were initial contributions by Prakash (1963a,b, 1973), Agrawal (1967), Biswas & Ghosh (1968) and Sinha (1970, 1973, 1975, 1976, 1977, 1996; Khandal et al. 2022).

Sinha (1980) was the first to conduct a systematic pan-Rajasthan study of Chiroptera in the state, apropos extensive surveys in the field and a detailed perusal of published literature. There were since also further contributions to the list of chiropteran species documented in the state by Sinha (1981), Sharma (1986), Bhupathy (1987), and Senacha & Dookia (2013). Srinivasulu et al. (2013) also authored a very detailed chapter on species believed to occur in the state (Khandal et al. 2022).

Khandal et al. (2022) nevertheless documented that there was no empirical evidence for the occurrence of three species: *Eptesicus serotinus pachyomus* Tomes, 1857, *Barbastella darjelingensis* Hodgson, in Horsfield, 1855 and *Myotis blythii* Tomes, 1857. An extensive survey of published literature revealed that the three species were not initially claimed to occur in Rajasthan at all, and that their inclusion in accounts on chiropteran species occurring in Rajasthan was a result of the perpetuation of assumed occurrence information (Khandal et al. 2022).

Tickell's Bat *Hesperoptenus tickelli* (Blyth, 1851), has not been reported for over a century in Rajasthan. Why has this species never been encountered in the state afterwards? Bates & Harrison (1997) raised the possibility of the occurrence of the Small Mouse-tailed Bat *Rhinopoma muscatellum* Thomas, 1903, in Rajasthan, but why did Bates & Harrison (1997) themselves mark the locality with a "?" in an accompanying distribution map? The authors therefore propose a review of published literature like the one in Khandal et al. (2022), on *H. tickelli* and *R. muscatellum*, to determine precisely why there might be no empirical evidence for their occurrence in Rajasthan.

OBSERVATIONS

Tickell's Bat *Hesperoptenus tickelli* (Blyth, 1851)

Bates & Harrison (1997) in their book 'Bats of the Indian Subcontinent', mentioned the locality of Nasirabad in Rajasthan for *H. tickelli* by citing "INDIA: Rajasthan: Nusserabad" (Blanford 1888–91). However, Bates & Harrison (1997) do not show this locality on their distributional map for *H. tickelli* and it is not specified why. This species occurs in India, Sri Lanka, Bhutan, Nepal, and Myanmar; within India, it occurs in localities in Maharashtra, Goa, Karnataka, Odisha, Jharkhand, Chhattisgarh, West Bengal, and the Andaman Islands (Bates & Harrison, 1997). However, it is not in Blanford (1889–91) but in Dobson's (1878) 'Catalogue of Chiroptera in the British Museum' that we first see mention of the locality "Nusserabad, India" in connection to specimens of *Vesperugo tickelli* from the "E.I. House Collection". This is the first mention of specimens from the ambiguous location in India—Nusserabad. There is also no mention of the name of the collector or the date of collection of these specimens, and in a span of almost a century and a half since, no reports of occurrence from 'Nasirabad' nor any other locality in Rajasthan.

An examination of 'A Catalogue of the Mammalia in the Museum of The Hon. East India Company' by Horsfield (1851), only includes a reference to a "dried specimen" for *Nycticejus isabellinus* that had been presented by the Asiatic Society of Bengal with the description "Hab. Central India". Anderson's (1881) 'Catalogue of Mammalia in the Indian Museum, Calcutta' provides details of the specimens collected from Chaibasa (Jharkhand) (type specimen) by S.R. Tickell in 1842, the Andaman Islands by R.C. Tytler in 1864, Singhbum (Jharkhand) by an unnamed museum collector in 1869, Surguja (Chhattisgarh) by W.T. Blanford in 1871, and from Jashpur (Chhattisgarh) and Tenasserim (Myanmar) by W.T. Blanford in 1871 and 1878, respectively. There is no mention of any specimen collected from 'Nusserabad'. It is Blanford (1888–91) who first connected Rajasthan to this species, "Peninsula of India (Nusserabad in Rajputana; Bombay; Chybassa; Jashpur, Sirguja in SW Bengal)" for *Vesperugo tickelli*.

Blanford (1888–91) thus connected the ambiguous locality of Nusserabad which was first mentioned by Dobson (1878) as just "Nusserabad, India" to "Rajputana". Blanford (1888–91) cited the published literature on this species at the time (Blyth 1851, 1863; Horsfield 1851; Kelaart 1852; Dobson 1876, 1877, 1878; Anderson 1881) in his account. Therefore, it appears that the inclusion of Rajputana (now Rajasthan) was assumed by Blanford (1888–91). What could have informed such an assumption by Blanford (1888–91)? As seen in Khandal et al. (2022) there were (and still are) several towns called 'Nasirabad' in India (at least three outside of Rajasthan in Uttar Pradesh, Maharashtra, and Madhya Pradesh in modern-day India). In British India (including modern-day Pakistan), the number of localities named 'Nasirabad' would climb to at least six. So why specifically 'Nasirabad' in Rajasthan?

Although he is not named in accounts connected to this species (Blyth 1851, 1863; Horsfield 1851; Kelaart 1852; Dobson 1876, 1877, 1878; Anderson 1881; Blanford 1888–91; Wroughton 1918; Ellerman & Morrison-Scott 1951; Sinha 1980; Bates & Harrison 1997; Srinivasulu et al. 2013), it was the association of the reputed cavalry officer-cum-specimen collector Captain W.J.E Boys to the cantonment town of Nasirabad in Rajasthan, that drove early naturalists to perpetuate similar assumptions in connection to three other bat species (Khandal et al. 2022). It is therefore possible that a similar sequence of events transpired because of the absence of a precise locality and collector information for the relevant specimens in Dobson's (1878) account. Following Blanford's (1888–91) inclusion of 'Rajputana' to the occurrence area of this species, Wroughton (1918) was the next to further perpetuate this assumption. In the Bombay Natural History Society's Mammal Survey of India, Burma (Myanmar) and Ceylon (Sri Lanka), Wroughton (1918) wrote "Other localities: Rajputana, Thana district, Bombay; Kanara; Madras (Jerdon) (B.M.)" for this species. Therefore, like Blanford (1888–91), it appears that Wroughton (1918) also interpreted Dobson's (1878) "Nusserabad, India" to mean Rajputana (B.M. = British Museum), for Jerdon (1874) does not mention any locality in Rajasthan for this species. All the specimens obtained in the survey, however, were obtained from other parts of India (Wroughton 1918; Bates & Harrison 1997). Like Wroughton (1918), Ellerman & Morrison-Scott (1951) further perpetuated the assumption of 'Rajputana' in the occurrence area of this species in their checklist of Palearctic and Indian Mammals—1758 to 1946, "India—Rajputana, Orissa, Bombay, Madras, Ceylon, Bengal, Bhutan duars (Blanford also quoted it from the Andaman Islands and Moulmein district, Burma)".

Sinha (1980), however, wrote the following on the occurrence of *H. tickelli* in Rajasthan, "RAJASTHAN: Wroughton (1918) and Ellerman & Morrison-Scott (1951) include "Rajputana" (=Rajasthan) in its range of distribution, but no precise localities are mentioned. I have not been able to collect any' example but as informed by J.E. Hill (Brit. Mus.), the exact locality of this species is Nasirabad (Rajasthan)". Sinha (1980) thus ignored Dobson (1878) and Blanford (1888–91) in his review of literature but relied on the late J.E. Hill of the British Museum. J.E. Hill was consistent with Blanford's (1888–91) assumption by connecting Nasirabad or Nusserabad to Rajasthan. Hill it should be noted however, also perpetuated similar assumptions with other bat species (Khandal et al. 2022).

Like Bates & Harrison (1997) before them, Srinivasulu et al. (2013) also include the assumed locality Nasirabad in Rajasthan for *H. tickelli* by citing Blanford (1888–91). "Blanford puts on record the presence of *Hesperoptenus tickelli* (Blyth, 1855) from Nasirabad." Srinivasulu et al. (2013) thus also ignore Dobson (1878), who first wrote of specimens collected from the ambiguous locality of Nusserabad in India. Blanford (1888–91) was the first to connect Nusserabad to Rajputana or Rajasthan, causing every subsequent author to assume that *H. tickelli* had been documented in Rajasthan.

In addition, an examination of specimen deposits in the Natural History Museum of London (NHM) (separated from the British Museum in 1963), and the Muséum d'histoire Naturelle Genève revealed no specimens from Rajasthan (GBIF 2023a). Similarly, an extensive examination of the Journal of the Bombay Natural History Society (JBNHS) revealed no specimens from Rajasthan collected in surveys nor specimen donations in proceedings for this species (Wroughton 1899, 1912, 1913, 1915, 1917, 1918; Brosset 1962; Hill 1967).

Small Mouse-tailed Bat *Rhinopoma muscatellum* Thomas, 1903

While doubting the record of this species for India, Bates & Harrison (1997) nevertheless categorically articulated the possibility of *R. muscatellum* specimens being collected from a locality called Genji in Rajasthan, "Tamil Nadu: Genji (doubtful record, restricted to Coromandel coast by Van Cakenberghe & de Vree (1994) but possibly Genji in Rajasthan)". Bates & Harrison (1997) also marked Genji in Rajasthan, along with a locality in Tamil Nadu with a "?" in a distributional map of *R. muscatellum* lending further credibility to this possibility. Considering that two species belonging to the same genus do occur in Rajasthan, namely *R. hardwickii* and *R. microphyllum* (Srinivasulu et al. 2013), the possibility of the occurrence of this species in Rajasthan has informally begun to gain plausibility. It is also possible that when viewed alongside occurrence reports in Afghanistan and Pakistan, a report from a locality in Rajasthan appeared to be a plausible extension of its occurrence area to Bates & Harrison (1997).

According to Van Cakenberghe & de Vree (1994), the source Bates & Harrsion (1997) cite for this assumption, this species was likely collected at a locality called 'Genji' on the Coromandel coast in southeastern India based on documentation provided with preserved specimens in the Museum National d'Histoire Naturelle in Paris. Curiously, however, they were unable to find a locality named 'Genji' in the area. While Van Cakenberghe & de Vree (1994) merely acknowledged that there was also a locality named "Genji" in Rajasthan and concluded that the specimens were from southeastern India, Genji in Rajasthan was nevertheless marked on their distributional map for *R. muscatellum*, thereby lending credence to the possibility that the specimens could have been collected in Rajasthan for the very first time. Van Cakenberghe & de Vree (1994) also add the following about both the collector and the specimens, "Mr. MAURICE MAINDRON – was in the neighbourhood of Pondicherry and Karikal in September 1901, the period in which these specimens were captured in Genji. Both localities are indeed situated on the Coromandel Coast". It should also be noted that early European naturalists in India were not necessarily consistent with the spellings of the names of localities (as we have already seen with Nusserabad or Nasirabad). While a locality spelt 'Genji' might not be located on the Coromandel coast in Tamil Nadu, the authors have noted a locality in close proximity to the coast named, 'Gingee' (12.2529^0N, 79.4160^0E) (Anonymous 2023). Thus, it is possible that this locality is what Maindron meant by 'Genji'.

Therefore, it is highly improbable that Maurice Maindron ventured to Genji in Rajasthan in 1900–1901. In addition to being inconsistent with what is documented about Maindron's travels (Van Cakenberghe & de Vree 1994), there is no documentation nor evidence of the occurrence of *R. muscatellum* in Rajasthan, despite a long history of chiropteran exploration in the state which has included numerous field surveys. In consideration of the above information, a contemporary survey of the field for *R. muscatellum* in Genji, Rajasthan appears unwarranted.

It should also be noted that the collector of the specimens, Maurice Maindron (1857–1911) had embarked on "25 years of almost continuous travel" after his employment by the Museum National d'Histoire Naturelle in Paris in 1875. His travels took him to, "New Guinea (1876–1877), Senegal (1879 and 1904), India (1880–1881, 1896, and 1900–1901), Indonesia (1884–1885), Djibouti and Somalia (1893), and Arabia (1896)" (Beolens et al. 2011). Considering that Maindron did indeed travel to other parts of the range of *R. muscatellum* such as 'Arabia', it is possible that the specimens were collected in a locality in west Asia (possibly the Persian Gulf where the species is known to occur today) and subsequently mislabelled. This is not out of the realm of possibility, as Benda & Mlíkovský (2008) noted that errors by curators did occur in the British Museum historically (Khandal et al. 2022). Therefore, we are of the opinion that Bates & Harrison (1997) were prudent in considering this record of *R. muscatellum* to be "doubtful" for India. Koopman (1993) excluded India and mentioned its distribution only from "Oman, W Iran, S Afghanistan, perhaps Ethiopia". Following this exclusion, Alfred et al. (2002), Srinivasulu & Srinivasulu (2012), Srinivasulu et al. (2013), and Talmale & Saikia (2018) also did not include *R. muscatellum* in the Indian chiropteran list.

As with *H. tickelli,* an examination of specimen deposits in the Natural History Museum of London (NHM), and Muséum d'histoire Naturelle Genève also revealed no specimens from not only Rajasthan, but none from India (GBIF 2023b). A review of the Journal of the Bombay Natural History Society also revealed no specimen deposits from Rajasthan in surveys and proceedings.

DISCUSSION AND CONCLUSION

Our literature review reveals that even though these two species were never reported from Rajasthan, their inclusion among chiropteran species occurring in the state was a result of the perpetuation of assumptions, with reports of their occurrence in the state perpetuated simply because of their being published. The report of *H. tickelli* follows a pattern of perpetuation observed in Khandal et al. (2022), while the report of *R. muscatellum* serves as a contemporary example of a similar phenomenon. However, it is important to note that historical observers were not systematic (Boshoff & Kerley 2010), and Blanford (1888–91) who first assumed that *H. tickelli* was reported from Rajasthan serves as a pertinent example. This is however by no means an isolated incident.

Blanford (1888–91) also claimed that *Hipposideros diadema* Geoffroy, 1813 had been "found by Mr. V Ball at Udaipur". Udaipur is located in southern Rajasthan. This report of occurrence in Rajasthan curiously does not follow the pattern of perpetuation observed in this review with *H. tickelli* and the three species observed in Khandal et al. (2022). Despite extensive chiropteran surveys, to date there is no evidence of the occurrence of *H. diadema* in Rajasthan, and it is only known to occur in, "the Nicobar Islands and Myanmar to Thailand, Malaysia, Indonesia, New Guinea, northern Australia and the Philippines" (Bates & Harrison 1997). The fact that the report of *H. diadema* does not follow the same pattern of perpetuation as *H. tickelli* and the three species observed in Khandal et al. (2022) only buttresses the notion that historical observers were not systematic and at times resorted to data selection and interpretation methods that can only be described as arbitrary.

There could be multiple causes for error with the reporting of occurrence localities, and then the perpetuation of erroneous occurrence reports. The report of *H. diadema* could very well have been the result of species misidentification by the collector. Misreading and misinterpretation of existing literature is yet another causal factor. For example, Khandal et al. (2023) documented that an erroneous citation led to the perpetuation of the false report that the first occurrence record of *Hipposideros lankadiva* in Rajasthan was from the Bhim Bharak caves in Jodhpur district. A literature review by Khandal et al. (2023) revealed that the cited text mentioned another species altogether, *Hipposideros fulvous* by Wason (1978).

Assumptions, however, can skew the reporting of occurrence localities and further result in the perpetuation of erroneous results. Boshoff & Kerley (2010) have documented that a paucity of geographical knowledge by historical observers can misinform historical occurrence data. The pattern of the perpetuation of the possibility of the occurrence of *R. muscatellum* in Rajasthan by Van Cakenberghe & de Vree (1994) and Bates & Harrison (1997) has shown that this is also possible in contemporary scientific literature. Historical occurrence data bears relevance to conservation biology and thus can have policy and management implications (Boshoff & Kerley 2010). The perpetuation of erroneous historical occurrence data can therefore have very damaging consequences for ecosystems. Therefore, pending the documentation of empirical evidence of occurrence, *H. tickelli* must be omitted from accounts of Chiroptera occurring in Rajasthan, and *R. muscatellum* from accounts of Chiroptera occurring in India.

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COMMUNICATION

Preference of *Helopsaltes pleskei* (Taczanowski, 1890) (Aves: Passeriformes: Locustellidae) on uninhabited islets (Chengdo, Jikgudo, and Heukgeomdo) in South Korea as breeding sites

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Abstract: This study was conducted to investigate the habitat and breeding status of the Pleske's 22 Grasshopper Warbler *Helopsaltes pleskei* inhabiting unmanned coastal islets (Cheongdo, Jikgudo and Heukgeomdo) on the Jeju Chuja Marine Provincial Park in South Korea. A total of 13 nesting sites were observed between April 2019 and April 2021. On Cheongdo Islet, nests were located as follows: four in *C. japonica*, one in *P. thunbergii*, and one in *Eurya emarginata*. On Jikgudo Islet, four nests were distributed with two in *C. japonica*, one in *P. thunbergii*, and one in *E. macrophylla*. Meanwhile, on Heukgeomdo islet, three nests were located, all in *C. japonica*. During the study period, 36 individuals were observed: 14 in Cheongdo, 10 in Jikgudo and 12 in the Heukgeomdo Islets. Most nesting sites were located in the bushy areas of the inner islets. Thus, birds tended to select nesting locations in response to predation and microclimates to increase reproductive rates and maximize offspring survival. This study highlights the importance of unmanned islands (islets) and the presence of bushy shrubs as important nesting and hiding sites for the ecologically vulnerable Pleske's Grasshopper Warbler.

Keywords: Defence mechanism, habitat environment, Korean Peninsula, Pleske's Grasshopper Warbler, Red List species, vegetation.

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Author details: Young-Hun Jeong and Sung-Hwan Choi are doctoral candidates specializing in ecology at Jeju National University. Young-Hun Jeong's research centers on the circadian rhythms of mammals and birds, and he is actively involved in bird monitoring and habitat surveys. Sung-Hwan Choi delves into the impact of alien species on the uninhabited islands of Jeju, emphasizing the ecological changes these species induce. Dr. Seon-Mi Park serves as a postdoctoral researcher at Jeju National University. Renowned for her expertise in molecular and animal ecology, she has published extensively in international academic journals, primarily focusing on invasive animal species. Dr. Jun-Won Lee has undertaken comprehensive research on the rodents of Jeju Island, earning his doctoral degree from Jeju National University. Professor Hong-Shik Oh has made seminal contributions to the field of ecology in South Korea. His areas of expertise encompass wildlife ecology, molecular ecology, genetics, and conservation biology.

Author contributions: YHJ drafted the original manuscript, while both YHJ and SHC conceptualized the study and designed the field methodology. YHJ, SHC, SMP, and JWL conducted the field study, collecting data, and performing the analysis. HSO reviewed and provided edits to the original manuscript.

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INTRODUCTION

Pleske's Grasshopper Warbler *Helopsaltes pleskei* is a species of Passeriformes, and is 17 cm long, with a greyish brown or olive brown back and white belly (Birdlife International 2001). The light brownish-white eyebrow line is unclear, the tail is round and small white spots at the end are observed and the legs are pale apricot (Fujita et al. 2005). Its appearance is similar to that of *Locustella ochotensis* and it feeds on insects, spiders, and gastropods (Lee et al. 2020). The Pleske's Grasshopper Warbler lays three to six eggs in reed fields, bamboo forests, and shrubberies around the coast between mid-May and August and builds rice bowl-shaped nests on shrub stems such as that of *Camellia japonica* and *Pittosporum tobira* (Brazil 2009).

The Pleske's Grasshopper Warbler is an extremely rare bird, with an estimated 2,500–10,000 individuals remaining worldwide. It is an internationally protected species classified as 'Vulnerable' (VU) as per the IUCN Red List and is also designated as belonging to endangered wildlife class II in South Korea (NIBR 2019). It breeds locally on the islands and coasts of far east Russia, Japan, and China, including the Korean Peninsula. Vietnam and Hong Kong are migratory locations (Qiao et al. 2006). Its habitat is usually an area in the shrubberies or wetlands located in temperate and subtropical climates, and fewer than 100 pairs of Pleske's Grasshopper Warblers are estimated to breed in Korea (Birdlife International 2001). It breeds mainly on uninhabited islands such as Hongdo, Chilbaldo and Sasudo Islets in South Korea (Choi et al. 2017). Habitat reduction and loss due to development are the main factors that have led to a decrease in the population of the Pleske's Grasshopper Warblers; however, no specific basis for this population reduction has been revealed yet (Takaki et al. 2001).

The records of this species were majorly based on past reports, and no field surveys have been conducted since 2016. Such information gaps also have significant conservation implications as they critically undermine the efforts in biodiversity conservation (Geijzendorffer et al. 2016). Hence, this study was conducted to identify nest structure and habitat characteristics and to provide the basic data for the protection of the threatened Pleske's Grasshopper Warblers.

MATERIALS AND METHODS

Study area

Chujado Island (33°56'94.7" N & 126°20'41.0" E) belongs to Jeju City, Jeju Special Self-Governing Province, South Korea (You et al. 2010). Near Chujado Island, there are 38 uninhabited islets, including Cheongdo, Jikgudo, and Heukgeomdo Islets. Among them, we selected the Cheongdo, Jikgudo, and Heukgeomdo Islets as study sites, and they can be accessed through ships (Figure 1). In the Cheongdo Islet, 62% of the total area (240,860.1 m^2) covered with vegetation is located on the central part of the islet, and 38% of the total area is covered by rocky land with exposed rocks. The covered area of Jikgudo Islet (240,318.4 m^2) is 62.7% of the total area, and the rocky land with exposed rocks occupies 37.3% of the total area (Korea National Park Service 2019). Of the total area (244.266.3 m^2) of the Heukgeomdo Islet, 72% of the area is covered with vegetation and is located on the central part of the islet, and 28% of the area is covered by rocky land. The climatic conditions of Chujado Island are characteristic of the southern west coast type of the Korean climatic zone, with an average annual temperature of 13.8° C and annual precipitation of 1,391 mm.

On-site investigations

We performed on-site investigations from April 2019 to April 2021 in the uninhabited Cheongdo, Jikgudo, and Heukgeomdo Islets. A line census method was used with binoculars (Swarovski, 10 × 42 BA, Austria) for individual investigation. Two people were grouped to identify the species and population. We visited the breeding sites during the breeding season (early May to end of August) to mark the nesting areas using a GPS MAP 64s (Garmin International, Kansas, USA).

Nest environment

Breeding nests were identified using binoculars (Swarovski, 10 × 42 BA, Austria) and a field scope (Swarovski, 20 × 60), and photographs were taken using a camera (Canon EF 500 mm, Canon, Japan). An unmanned sensor camera (Bushwhacker, ROBOT D30, Shenzhen, China) was used to continuously photograph the nest when Pleske's Grasshopper Warblers started building the nests (Image 1). The unmanned sensor camera was installed more than 10 m from the breeding nest to prevent it from interfering with breeding. To measure nesting tree height, and nest diameter, we used a digital distance meter (Digital Range Finder; Leica DISTOTM X10; Mitutoyo, unit 0.05 mm)

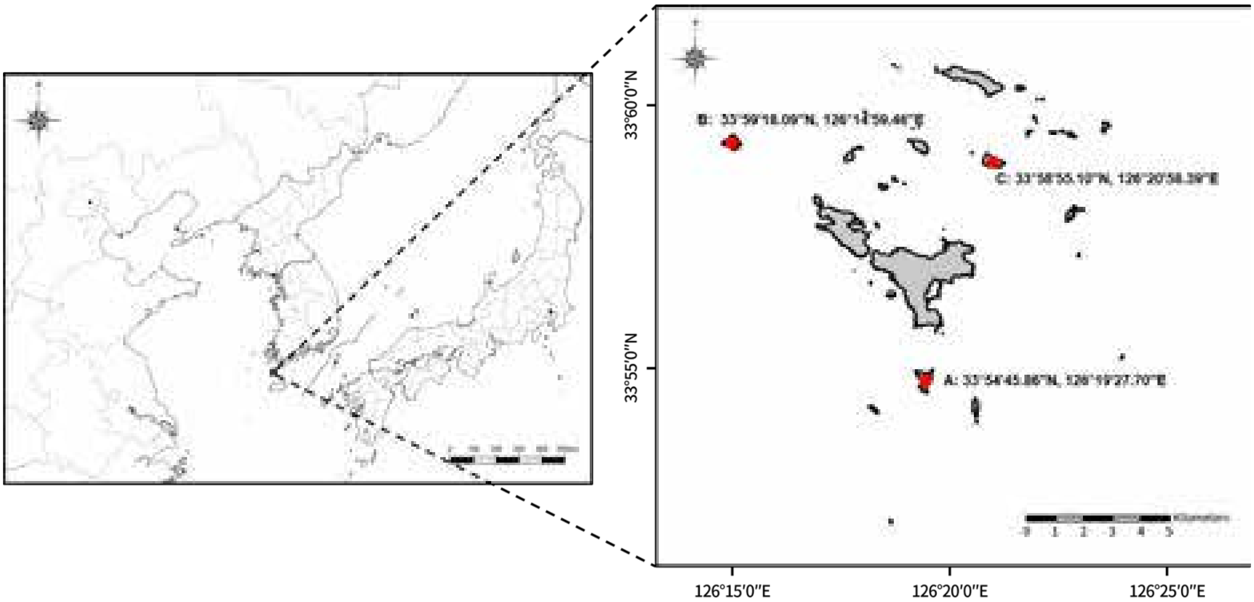

Figure 1. Distribution of the Pleske's Grasshopper Warbler breeding sites on unmanned islets (Cheongdo, Jikgudo, and Heukgeomdo) around Chuja Island, South Korea: A— Cheongdo I B—Jukgudo I C—Heukgeomdo.

Vegetation Colony

We investigated the vegetation status (colony structure) by selecting vegetation points such as trees, sub-trees, shrubs, and herbaceous layers. Furthermore, we investigated the vegetation dominance rate using the Braun-Blanquet cover-abundance scale (Wikum & Shanholtzer 1978).

RESULTS

Habitat status

The nesting sites of the Pleske's Grasshopper Warblers were identified in three islets: Cheongdo, Jikgudo, and Heukgeomdo. On Cheongdo Islet, nests were located as follows: four in *C. japonica*, one in *P. thunbergii*, and one in *Eurya emarginata*. On Jikgudo Islet, four nests were distributed with two in *C. japonica*, one in *P. thunbergii*, and one in *E. macrophylla*. Meanwhile, on Heukgeomdo islet, three nests were located, all in *C. japonica*. A total of 14, 10, and 12 individuals were found in Cheongdo, Jikgudo and Heukgeomdo Islets, respectively. The Pleske's Grasshopper Warblers in the study area started breeding in early May and began vocalizing to secure territory, and individuals incubated until the end of July. The areas of vegetation of Cheongdo Islet were 45% grassland, 16.9% forest land, and 0.1% shrubland (Figure 2). The main colonies that made up the forestland were *P. thunbergii* (8.1%) followed by *E. emarginata* (7.3%). *C. japonica* formed small colonies. *P. thunbergii* is widely distributed on the southeastern slope and *C. japonica* is mainly distributed on the northern slope (Korea National Park Service 2019). The areas of vegetation of Jikgudo Islet were 25.1% grassland, 31.0% forestland, and 6.6% shrubland. The main colonies that made up the forestland were *E. emarginata* (12.8%) followed by *C. japonica* (11.1%). *P. thunbergii* formed small colonies. *E. emarginata* was distributed from the northern slope to the eastern slope, and *C. japonica* formed on the central and southwestern slopes of this islet. The areas of vegetation of Heukgeomdo Islet were 34.3% forestland, 33.6% grassland, and 6.6% shrubland. The main colonies that made up the forestland were *P. thunbergii* (17.1%) and *C. japonica* (16.4%). *Celtis sinensis* and *Rhus javanica* formed small colonies.

Nesting environment

The 13 Pleske's Grasshopper Warbler nests observed in this study, were nested in *P. thunbergii* and *C. japonica*. The warblers built nests inside coniferous trees, whereas they built nests in relatively large leaves in lush, broad-leaved evergreen trees.

In Cheongdo Islet, the nest height, nesting tree height and nest cup diameter were 1.69 ± 0.13 m (range: 1.48–1.85 m), 3.73 ± 1.21 m (range: 2.89–4.12 m) and 10.01 ± 0.32 cm (range 9.71–10.45 cm), respectively (Table 2). In Jikgudo Islet, the nest height, nesting tree height and nest cup diameter were 1.41 ± 0.07 m (range: 1.33–1.51 m), 3.01 ± 0.13 m (range: 2.85–3.13 m) and 9.83 ± 0.33 (range: 9.58–10.33), respectively. In Heukgeomdo

Table 1. Nest tree preference and the number of Pleske's Grasshopper Warblers on the South Korean study sites.

Study site	No. of individuals	No. of trees used for nesting and breeding			
		Pinus thunbergii	*Eurya emarginata*	*Camellia japonica*	*Elaeagnus macrophylla*
Cheongdo	14	1	1	4	
Jikgudo	10			2	1
Heukgeomdo	12			3	

Table 2. Dimensions of the nest height, nesting tree height, and nest cup diameter of the South Korean breeding sites of Pleske's Grasshopper Warblers.

Nest location / Division	Cheongdo		Jikgudo		Heukgeomdo	
	Value	Range	Value	Range	Value	Range
Nest height (m*)	1.69 ± 0.13	1.48–1.85	1.41 ± 0.07	1.33–1.51	1.34 ± 0.18	1.19–1.63
Nesting tree height (m*)	3.73 ± 1.21	2.89–4.12	3.01 ± 0.13	2.85–3.13	3.10 ± 0.28	2.77–3.53
Nest cup diameter (cm*)	10.01 ± 0.32	9.71–10.45	9.83 ± 0.33	9.58–10.33	9.3 ± 0.44	8.56–9.69

*— Standard deviation

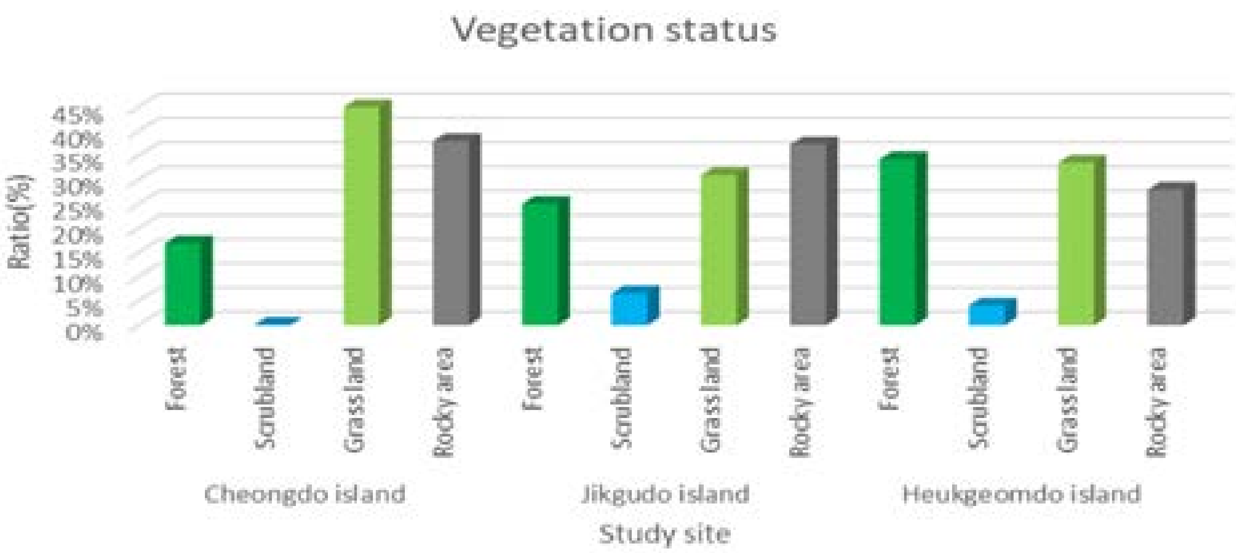

Figure 2. The ratio of the vegetation in the uninhabited islands of the Chuja Marine Provincial Park: Chengdo, Jikgudo, and Heukgeomdo islets.

Islet, the nest height, nesting tree height and nest cup diameter were 1.34 ± 0.18 m (range: 1.19–1.63 m), 3.10 ± 0.28 m (range: 2.77–3.53 m) and 9.3 ± 0.44 cm (range: 8.56–9.69 cm), respectively.

DISCUSSION

In response to predation and microclimate, birds select nesting locations to increase breeding rates and maximize the survival rates of their young (Gómez-Serrano & López-López 2017). Vegetation is crucial for maintaining a thermal environment by controlling the micro-weather conditions, thereby reducing the effects of wind and direct sunlight, while simultaneously hiding the nest to reduce the probability of predation (Kim et al. 2009; Kearns & Rodewald 2013). Particularly, microclimate has a significant impact on the energy efficiency of eggs, young and gonads; therefore, the location, entrance direction and height of nests are adjusted to select microhabitats that are effective for maintaining body temperature and are protected from

Image 1. Current status of Pleske's Grasshopper Warblers on the study sites: A—song indicating territorial defence l B—nest defence l C, D—nest of Pleske's Grasshopper Warbler on Eurya emarginata tree. © Young Hoon Jeong

extreme weather factors (Polak 2019). Therefore, it is believed that nesting inside the islet and choosing trees with large and wide leaves, such as that in *C. japonica*, was caused by a defence mechanism to protect young from predatory pressure and to reduce nest exposure from birds of prey, such as the Peregrine Falcon, and by reducing the effects of sea breezes to maintain warmth (Montgomerie & Weatherhead 1988).

Comparing the habitat environments of Pleske's Grasshopper Warbler nests identified so far in Korea and Japan, Nagata (1993) and Park & Seo (2008) observed nests among lush herbs, and Kim et al. (2009) confirmed that nests were built in bushes. Choi et al. (2017) identified potential brooding sites on the steeply sloped areas on the island. In Japan, the Pleske's Grasshopper Warblers arrived between late April and June and began breeding (Takaki et al. 2001), and the warblers in the unmanned island breeding sites in the central and southern regions of South Korea began breeding in May and June (NIBR 2017). In our study area, the Pleske's Grasshopper Warblers arrived in mid-May and began breeding from the end of June through August. These results tend to coincide with the breeding period and ecology of its living in the Japanese archipelago.

To date, the area of distribution of this species is limited to Russia, China, the Korean Peninsula, and Japan. As the latitude rises, breeding records become very rare (BirdLife International 2023). Therefore, except for the migration period, it is believed that this species will move south from Russia and breed in island areas near the Korean Peninsula and Japan. We found that the nest was built in subtrees such as *C. japonica*, *P. thunbergii*, and *E. emarginata*, which was similar to the results of Kim et al. (2009). As a result, Pleske's Grasshopper Warblers can be said to prefer shrubbery as a breeding nest.

Much still needs to be studied about the distribution, abundance, and habitat requirements of this species. Its threatened status and conservation requirements can be clarified by research targeted at the following areas:

(1) monitoring surveys to locate additional populations on islands within the potential breeding range in South Korea; (2) ecological studies at selected breeding sites to determine population and habitat requirements during the breeding season; (3) population studies comparing to past to determine whether there have been changes in the numbers and distribution since the original records; and (4) Capture-recapture surveys to locate populations in potential sites.

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COMMUNICATION

Avifaunal diversity of Tsirang District with a new country record for Bhutan

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Abstract: Birds play a vital role in ecosystems. Studying avifaunal diversity therefore has a noteworthy role in indicating nature's ecological balance in the environment. A total of 749 bird species have so far been recorded in Bhutan. We present a comprehensive checklist of birds of Tsirang, District which largely lies outside Bhutan's protected area system. The data was collected through opportunistic encounters and with regular field visits to a range of locations in different seasons. One-fourth of the country's total avifauna and a new species recorded for Bhutan, The Plum-headed Parakeet *Psittacula cyanocephala* was recorded as part of this study. In all, 285 avian species belonging to 18 orders and 65 families including one globally 'Critically Endangered', three 'Vulnerable', and a 'Near Threatened' species were recorded during the survey. The high species richness of birds in the study area reveals that it includes good habitats for birds in Bhutan. Similar studies are suggested in other areas contiguous to the protected areas in Bhutan including the current study area. This should aid in understanding of the factors driving the differences in bird diversity within and outside the protected areas so as to facilitate informed conservation actions in future.

Keywords: Birds, broadleaved forests, checklist, conservation, IUCN Red List status, vegetation.

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Author details: Mr. Gyeltshen, an educator, is completing his M.Ed. in primary science at Paro College of Education, Royal University of Bhutan. He's committed to Mendrelgang Primary School, where he served passionately for over a decade. He co-authored "A Pictorial Field Guide to Birds of Tsirang" in 2020, showcasing his dedication to both education and nature. Mr. Sangay Chhophel, an educator by profession and currently works at Damphu Middle Secondary School in Tsirang under Ministry of Education and Skills Development, Bhutan. He has an MSc in Botany. This is his 14th years in the education system. He is a passionate birder and a photographer apart from his primary profession. Mr. Karma Wangda received his bachelor of education in secondary science from Samtse College of Education, Royal University of Bhutan in 2010 and his Master of Education in Biology in 2019. Since 2011, he has been working as Secondary Biology Teacher in various Schools in Bhutan. His research interest includes innovative pedagogies in STEM education, conservation biology, and sustainable development. Mr. Kinley worked as the head of the Wildlife and Nature Conservation Section in Tsirang Territorial Forest Division, Department of Forest and Park Services, Ministry of Energy and Natural Resources, Bhutan. He is keen on studying the ecology of endangered species, human-wildlife conflict, and the impact of climate change on wildlife and its habitat. He is currently studying Master's in Environment and climate Emergency at Curtin University in Western Australia. Mr. Tshering Penjor received his bachelor of life sciences in Sherabtse College, Royal University of Bhutan in 2015 and Post Graduate Diploma in Education in 2016 from Samtse College of education. Since 2017, he has been working as secondary Biology teacher in various schools in Bhutan. His research interest includes innovative pedagogies in STEM education and conservation biology. He has co-authored "Ethnomedicinal Practices in Kilikhar, Monger, 2018". Mr. Karma Dorji, who is a teacher by profession, is currently in the first year of his master's degree program in Primary Social Studies at Paro College of Education, Royal University of Bhutan. Before joining the college, he dedicated 17 years of service to various schools in Bhutan under the Ministry of Education, including Mendrelgang Primary School in Tsirang.

Author contributions: Mr. Gyeltshen assumed the principal role in originating this manuscript, encompassing responsibilities such as photography, data compilation, and revision of the reviewed draft. Mr. Sangay Chophel substantially contributed by supplying data and assuming a pivotal role in revising the manuscript. Likewise, Mr. Karma Wangda and Mr. Kinley contributed essential data and enhanced the manuscript's composition. Mr. Tshering Penjor and Mr. Karma Dorji provided references to distinct sections of the manuscript and actively participated in its revision. Collectively, each author made substantive and noteworthy contributions to the conception and maturation of this paper.

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INTRODUCTION

Described as 'feathered bipeds', birds are a very visible and integral part of the ecosystem (Ali 1941). Their roles include ecological health indicators, plant pollinators, and seed dispersers as well as pest regulators (Ali 1941; Bilgrami 1995; Harisha & Hosetti 2009).

It is said that the bird exploration in Bhutan began as early as 1937 by a team of foreigners from Britain (Ludlow & Kinnear 1937; Clements 1992; Gyeltshen et al. 2020). Since then, a number of studies on birds have been carried out in Bhutan which have contributed to developing baseline data. For example, Inskipp & Inskipp (1993) recorded 319 bird species, including 21 previously unpublished records for Bhutan.

The first detailed and comprehensive field guide titled 'Birds of Bhutan' recorded 616 species (Inskipp et al 1999). After two decades, the same team with an additional author from Bhutan published a new book titled 'Birds of Bhutan and the Eastern Himalayas', which is one of the latest comprehensive works on avifauna for Bhutan. According to Grimmett et al. (2019), Bhutan hosts 736 bird species. Since then, the Bhutan Birdlife Society (BBS) which is one of the latest civil society organizations (CSO) has shown through its Facebook group that 748 species have been recorded in Bhutan. The increase in the number of new records is attributed to a citizen science initiative as confirmed by ornithologists Tim Inskipp & Sherab (as cited in Dendup et al. 2020; Gyeltshen et al. 2020). With the recent sighting of Short-tailed Shearwater *Adenna tenuirostris* from Phibsoo Wildlife Sanctuary on 20 January 2021, a total of 749 species has been recorded in Bhutan (BBS 2021).

Bhutan is one of the Endemic Bird Areas (EBA) in the eastern Himalaya (Stattersfield et al. 1998; Bishop 1999). This is attributed to suitable climatic conditions, and the availability of natural resources in the region (Mohammad & Krishna 2016).

Bhutan has made a great effort to protect birds and their habitat. For example, the Biodiversity Conservation Act 2003 and Forest and Nature Conservation Rules and Regulations 2017 cover bird conservation, and 36 species (National Biodiversity Centre 2019) are listed as totally protected under schedule I.

MATERIAL AND METHODS

Study Area

Tsirang Forest Division jurisdiction is located in the south-central part of Bhutan (Figure 1). The total area of Tsirang is 638.8 km^2 and it is located between 27^{o}11'58.6" N - 27^{o}48'59.9" N and 90^{o}20' 57.7" E-90^{o}20'23.3" E in central Bhutan. Tsirang shares boundaries with three other districts: Wangdue Phodrang, Dagana, and Sarpang in central Bhutan. Tsirang has 12 blocks and 101 villages with a population density of 35.9 per km^2 (Tsirang 2021).

The vegetation in the district is predominantly broadleaved forest covering 77.64% of the land area. In addition, there are other forest types such as Chir Pine *Pinus roxburghii* forest covering 6.51%, fir *Abies* forest covering 0.40%, and mixed conifer forests covering about 2.95% at the outer reaches of the district (FRMD 2017). The other significant vegetation is shrubs at 3.30%, which make up the higher altitude mountain slopes to the north of the district.

A portion of Tsirang District in the north lies in Jigme Singye Wangchuck National Park (JSWNP) covering about 34 km^2 in Sergithang block and Phuntenchu block. Part of southeastern Tsirang lies in the biological corridor network which connects JSWNP, Royal Manas National Park (RMNP), and Phibsoo Wildlife Sanctuary (PWS). With a warm and temperate climate, the elevation of Tsirang ranges 200–4,500 m (FRMD 2017). It is inhabited by rural settlements distributed sparsely on the hills and gentle slopes.

Methods

The data was gathered through intentional and opportunistic records in most parts of the district to document avifaunal diversity with most of the records captured during our field visits. The areas covered are located at altitudes ranging 250–2,500 m. Bird watching was normally done in the early hours (0600–0900 h) and occasionally in the evening at around 1530–1800 h. This survey explored a wide range of habitats including forests, streams, artificial ponds, and cultivation to study bird diversity. Canon 1300D, Canon Rebel T5, Nikon D5100 DSLR cameras with a zoom lens of max 300 mm, and 8x42 binoculars were used for bird watching and to capture bird images.

Birds were identified to the species level with the help of various available field guides (Grimmett et al. 1999, 2019) and experts' identification through the Birds of Bhutan (Bhutan Birdlife Society) Facebook forum. The terminology is based on Manakadan & Pittie (2001).

The birds were categorized as A—Abundant (sighted

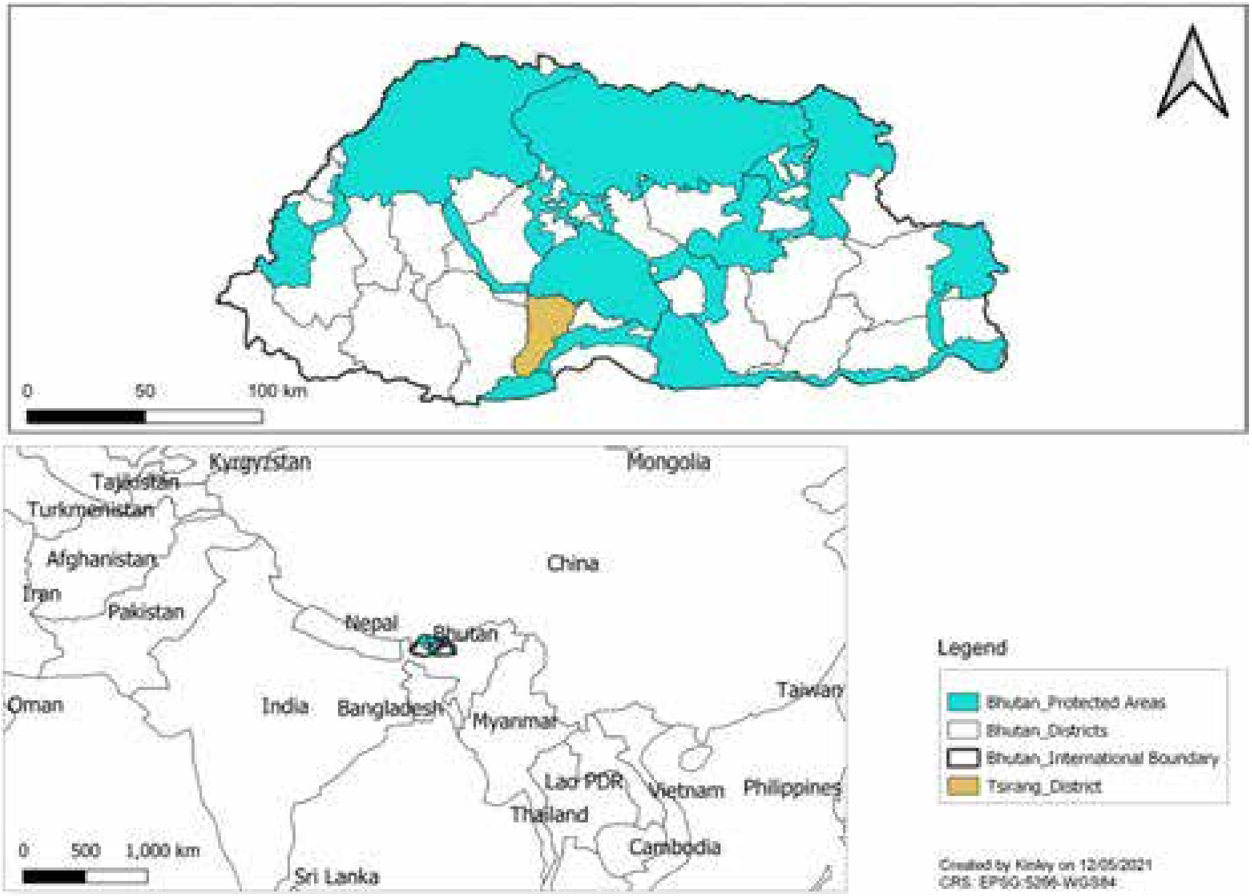

Figure 1. Study area where bird species were observed.

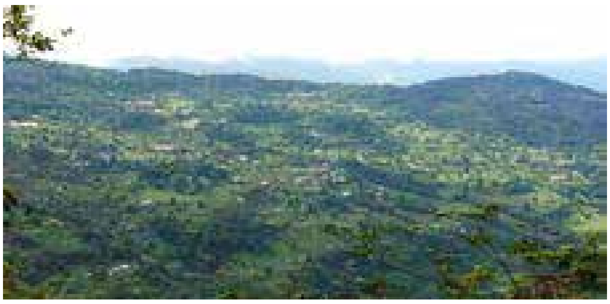

Image 1. A sparsely occupied and cultivated agricultural land of Mendrelgang Block. © Gyeltshen.

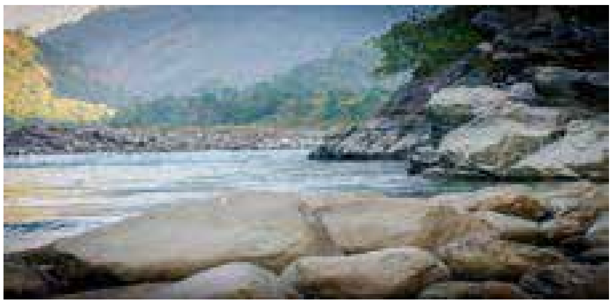

Image 2. At the lowest elevation of Sankosh River under Tsirang District. © Sangay Chhophel.

almost every time we go for bird watching in different sites); C—Common (sighted 10 times in the region); O—Occasional (sighted occasionally up to 5 times); and R—Rare (once or twice) based on the presence or absence during our visit to the areas.

RESULTS AND DISCUSSION

A total of 258 avian species belonging to 18 orders and 65 families was recorded (Table 1). The bird species were categorized by their order, abundance, and conservation status.

Among the total of 18 orders, Passeriformes was the dominant order comprising 71.3% (184 species in 45 families) of the total species recorded, followed by

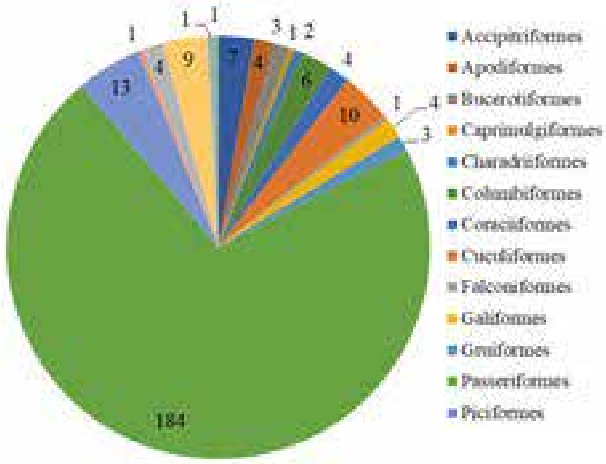

Figure 2. Number of bird species by order.

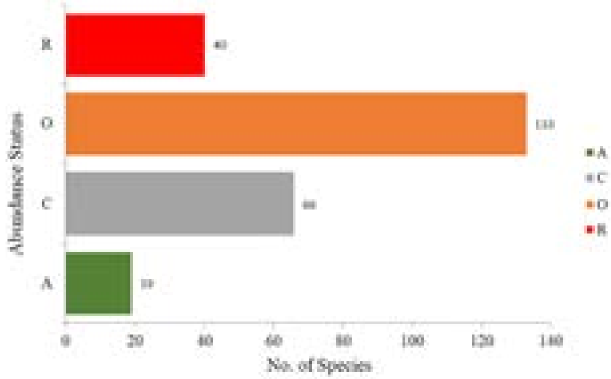

Figure 3. Abundance status: A—Abundant | C—Common | O—Occasional | R—Rare.

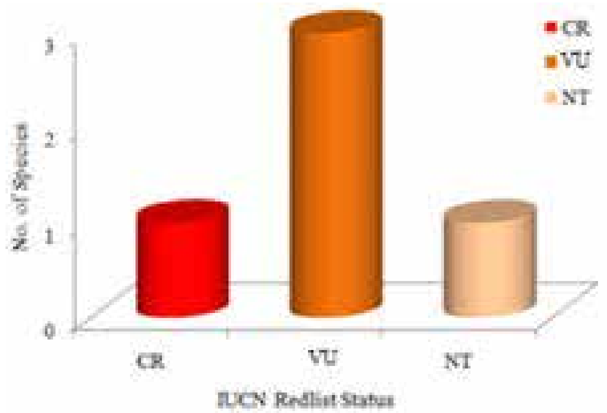

Figure 4. Classification by the IUCN Red List status

Piciformes (13 species in 2 families) with 5.03% of the total species count. Trogoniformes, Caprimulgiformes, Suliformes, and Psittaciformes were the least represented orders with a single species each (Figure 2).

The majority of bird species fall in the occasional group (O) with 51.5% (n = 133) of the total species recorded, followed by Common bird species (C) with 25.5% (n = 66) of the total, abundant species with 7.36% (n = 19) of the total and rarely sighted species with 7.4% (n = 19) of the total species recorded.

The results reported by Gyeltshen et al. (2020) in Trongsa District in central Bhutan also indicated that passerines were the most dominant order in which our result was consistent with Gyeltshen et al. (2020). The majority of bird recorded (253 species, 98% of the total) have been assessed as Least Concern (LC). Four globally threatened species were also sighted during the survey (Figure 4). Amongst the rarely sighted species is the globally 'Critically Endangered' White-bellied Heron *Ardea insignis* which occurs at 250 m along the Sankosh River, one of the longest rivers in the country, and its tributaries. The globally 'Vulnerable' Rufous-necked Hornbill *Aceros nipalensis* and Great Hornbill *Buceros bicornis* were recorded from different localities including Barshong, Sergithang, Patshaling, Phuentenchu, and Mendrelgang during the survey. The Beautiful Nuthatch (VU) *Sitta formosa* was recorded from the Daratsho area adjoining Sarpang district which lies in the biological corridor that connects JSWNP, RMNP, and PWS. The globally 'Near Threatened' species River Lapwing *Vanellus duvaucelii* was also recorded from the lowest altitude of Sunkosh River and Malbasay under Patshaling block.

A single male Tibetan Serin *Serinus thibetanus* was observed once at Patshaling Block in February 2017 by the roadside and the Sapphire Flycatcher *Ficedula sapphira* the following day at Mendrelgang block. Neither species was sighted subsequently despite consistent efforts to find them. Common Myna *Acridotheres tristis*, Rock Pigeon *Columba livia*, Eurasian Tree Sparrow *Passer montanus*, and White-crested Laughing thrush *Garrulax leucolophus* are abundant in the locality. The Plum-headed Parakeet *Psittacula cyanocephala* (Image 65) is a new record contributed to the list of Birds of Bhutan sighted first on 28 October 2018 at Mendrelgang block under Tsirang District at 2,100 m by the first author. The record was later verified and confirmed by Tim Inskipp & Sherab.

Most of the birds were observed and photographed at the edges of cultivation, along highways, on farms, and on roadsides. Many of these birds were recorded during the spring and autumn seasons.

Table 1. Checklist of bird diversity in Tsirang, Bhutan.

	Common name	Scientific name	Family	Categorization	IUCN Red List status
1	Rufous-throated Partridge	*Arborophila rufogularis*	Phasianidae	C	LC
2	Red Junglefowl	*Gallus gallus*	Phasianidae	C	LC
3	Indian Peafowl	*Pavo cristatus*	Phasianidae	R	LC
4	Kalij Pheasant	*Lophura leucomelanos*	Phasianidae	C	LC
5	Great Cormorant	*Phalacrocorax carbo*	Phalacrocoracidae	O	LC
6	Little Cormorant	*Microcarbo niger*	Phalacrocoracidae	R	LC
7	Black-crowned Night Heron	*Nycticorax nycticorax*	Ardeidae	R	LC
8	White-bellied Heron	*Ardea insignis*	Ardeidae	R	CR
9	Little Egret	*Egretta garzetta*	Ardeidae	R	LC
10	Oriental Honey-buzzard	*Pernis ptilorhynchus*	Accipitridae	O	LC
11	Jerdon's Baza	*Aviceda jerdoni*	Accipitridae	O	LC
12	Crested Serpent-Eagle	*Spilornis cheela*	Accipitridae	O	LC
13	Black Eagle	*Ictinaetus malaiensis*	Accipitridae	O	LC
14	Besra	*Accipiter virgatus*	Accipitridae	O	LC
15	Eurasian Sparrowhawk	*Accipiter nisus*	Accipitridae	O	LC
16	Common Buzzard	*Buteo buteo*	Accipitridae	O	LC
17	Slaty-breasted Rail	*Gallirallus striatus*	Rallidae	R	LC
18	Black-tailed Crake	*Zapornia bicolor*	Rallidae	C	LC
19	Barred Buttonquail	*Turnix suscitator*	Turnicidae	O	LC
20	River Lapwing	*Vanellus duvaucelii*	Charadriidae	C	NT
21	Red-watted Lapwing	*Vanelleus indicus*	Charadriidae	R	LC
22	Rock Pigeon	*Columba livia*	Columbidae	A	LC
23	Oriental Turtle-Dove	*Streptopelia orientalis*	Columbidae	A	LC
24	Spotted Dove	*Streptopelia chinensis*	Columbidae	A	LC
25	Barred Cuckoo-Dove	*Macropygia unchall*	Columbidae	A	LC
26	Wedge-tailed Green Pigeon	*Treron sphenurus*	Columbidae	A	LC
27	Mountain Imperial Pigeon	*Ducula badia*	Columbidae	O	LC
28	Asian Koel	*Eudynamys scolopaceus*	Cuculidae	R	LC
29	Green-billed Malkoha	*Phaenicophaeus tristis*	Cuculidae	O	LC
30	Chestnut-winged Cuckoo	*Clamator coromandus*	Cuculidae	O	LC
31	Plaintive Cuckoo	*Cacomantis merulinus*	Cuculidae	O	LC
32	Large HawkCuckoo	*Hierococcyx sparverioides*	Cuculidae	O	LC
33	Lesser Cuckoo	*Cuculus poliocephalus*	Cuculidae	O	LC
34	Indian Cuckoo	*Cuculus micropterus*	Cuculidae	R	LC
35	Himalayan Cuckoo	*Cuculus saturates*	Cuculidae	R	LC
36	Common Cuckoo	*Cuculus canorus*	Cuculidae	R	LC
37	Lesser Coucal	*Centropus bengalensis*	Cuculidae	O	LC
38	Mountain Scops-Owl	*Otus spilocephalus*	Strigidae	O	LC
39	Collared Scops-Owl	*Otus lettia*	Strigidae	O	LC
40	Brown Wood Owl	*Strix leptogrammica*	Strigidae	R	LC
41	Collared Owlet	*Glaucidium brodiei*	Strigidae	O	LC
42	Asian Barred Owlet	*Glaucidium cuculoides*	Strigidae	O	LC
43	Jungle Owlet	*Glaucidium radiatum*	Strigidae	R	LC
44	Spotted Owlet	*Athene brama*	Strigidae	R	LC

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45	Tawny Fish Owl	*Ketupa flavipes*	Strigidae	R	LC
46	Grey Nightjar	*Caprimulgus indicus*	Caprimulgidae	O	LC
47	White-throated Needletail	*Hirundapus caudacutus*	Apodidae	O	LC
48	House Swift	*Apus nipalensis*	Apodidae	O	LC
49	Himalayan Swiftlet	*Aerodramus brevirostris*	Apodidae	O	LC
50	Blyth's Swift	*Apus leuconyx*	Apodidae	O	NE
51	Red-headed Trogon	*Harpactes erythrocephalus*	Trogonidae	O	LC
52	Eurasian Hoopoe	*Upupa epops*	Upupidae	O	LC
53	Great Hornbill	*Buceros bicornis*	Bucerotidae	C	VU
54	Rufous-necked Hornbill	*Aceros nipalensis*	Bucerotidae	R	VU
55	White-throated Kingfisher	*Halcyon smyrnensis*	Alcedinidae	O	LC
56	Crested Kingfisher	*Megaceryle lugubris*	Alcedinidae	O	LC
57	Pied Kingfisher	*Ceryle rudis*	Alcedinidae	R	LC
58	Blue-bearded Bee-eater	*Nyctyornis athertoni*	Meropidae	O	LC
59	Great Barbet	*Psilopogon virens*	Megalaimidae	C	LC
60	Golden-throated Barbet	*Psilopogon franklinii*	Megalaimidae	O	LC
61	Blue-throated Barbet	*Psilopogon asiaticus*	Megalaimidae	C	LC
62	Speckled Piculet	*Picumnus innominatus*	Picidae	O	LC
63	White-browed Piculet	*Sasia ochracea*	Picidae	O	LC
64	Grey-capped Pygmy Woodpecker	*Dendrocopos canicapillus*	Picidae	O	LC
65	Fulvous-breasted Woodpecker	*Dendrocopos macei*	Picidae	O	LC
66	Lesser Yellownape	*Picus chlorolophus*	Picidae	O	LC
67	Greater Yellownape	*Picus flavinucha*	Picidae	O	LC
68	Grey-headed Woodpecker	*Picus canus*	Picidae	C	LC
69	Rufous Woodpecker	*Micropternus brachyurus*	Picidae	O	LC
70	Greater Flameback	*Chrysocolaptes guttacristatus*	Picidae	O	LC
71	Bay Woodpecker	*Blythipicus pyrrhotis*	Picidae	O	LC
72	Eurasian Kestrel	*Falco tinnunculus*	Folconidae	O	LC
73	Long-tailed Broadbill	*Psarisomus dalhousiae*	Eurylaimidae	O	LC
74	Blue-naped Pitta	*Hydrornis nipalensis*	Pittidae	O	LC
75	Large Woodshrike	*Tephrodornis virgatus*	Tephrodornithidae	O	LC
76	Bar-winged Flycatcher-shrike	*Hemipus picatus*	Tephrodornithidae	O	LC
77	Ashy Woodswallow	*Artamus fuscus*	Artamidae	O	LC
78	Common Iora	*Aegithina tiphia*	Aegithinidae	O	LC
79	Gray-chinned Minivet	*Pericrocotus solaris*	Campephagidae	O	LC
80	Long-tailed Minivet	*Pericrocotus ethologus*	Campephagidae	O	LC
81	Scarlet Minivet	*Pericrocotus speciosus*	Campephagidae	C	LC
82	Short-billed Minivet	*Pericrocotus brevirostis*	Campephagidae	O	LC
83	Large Cuckooshrike	*Coracina macei*	Campephagidae	O	LC
84	Black-winged Cuckooshrike	*Lalage melaschistos*	Campephagidae	O	LC
85	Brown Shrike	*Lanius cristatus*	Laniidae	R	LC
86	Long-tailed Shrike	*Lanius schach*	Laniidae	C	LC
87	Gray-backed Shrike	*Lanius tephronotus*	Laniidae	O	LC
88	Blyth's Shrike-Babbler	*Pteruthius aeralatus*	Vireonidae	O	LC
89	White-bellied Erpornis	*Erpornis zantholeuca*	Vireonidae	O	LC

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90	Slender-billed Oriole	*Oriolus tenuirostris*	Oriolidae	R	LC
91	Maroon Oriole	*Oriolus traillii*	Oriolidae	O	LC
92	Black Drongo	*Dicrurus macrocercus*	Dicruridae	R	LC
93	Ashy Drongo	*Dicrurus leucophaeus*	Dicruridae	A	LC
94	Bronzed Drongo	*Dicrurus aeneus*	Dicruridae	O	LC
95	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	Dicruridae	O	LC
96	Lesser Racket-tailed Drongo	*Dicrurus remifer*	Dicruridae	O	LC
97	Hair-crested Drongo	*Dicrurus hottentottus*	Dicruridae	O	LC
98	White-throated Fantail	*Rhipidura albicollis*	Rhipiduridae	O	LC
99	Common Green-Magpie	*Cissa chinensis*	Corvidae	O	LC
100	Grey Treepie	*Dendrocitta formosae*	Corvidae	C	LC
101	Barn Swallow	*Hirundo rustica*	Hirrundinidae	C	LC
102	Nepal House Martin	*Delichon nepalensis*	Hirrundinidae	O	LC
103	Red-rumped Swallow	*Cecropis daurica*	Hirrundinidae	C	LC
104	Yellow-bellied Fairy-Fantail	*Chelidorhynx hypoxantha*	Stenostiridae	C	LC
105	Grey-headed Canary-Flycatcher	*Culicicapa ceylonensis*	Stenostiridae	C	LC
106	Sultan Tit	*Melanochlora sultanea*	Paridae	O	LC
107	Green-backed Tit	*Parus monticolus*	Paridae	C	LC
108	Yellow-cheeked Tit	*Machlolophus spilonotus*	Paridae	O	LC
109	Black-throated Tit	*Aegithalos concinnus*	Aegithalidae	O	LC
110	Beautiful Nuthatch	*Sitta formosa*	Sittidae	R	VU
111	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*	Sittidae	O	LC
112	Velvet-fronted Nuthatch	*Sitta frontalis*	Sittidae	R	LC
113	White-tailed Nuthatch	*Sitta himalayensis*	Sittidae	O	LC
114	Wall Creeper	*Tichodroma muraria*	Tichodromidae,	R	LC
115	Hodgson's Treecreeper	*Certhia hodgsoni*	Certhiidae	O	LC
116	Brown Dipper	*Cinclus pallasii*	Cinclidae	O	LC
117	Striated Bulbul	*Pycnonotus striatus*	Pycnonotidae	O	LC
118	Black-crested Bulbul	*Pycnonotus flaviventris*	Pycnonotidae	O	LC
119	Red-vented Bulbul	*Pycnonotus cafer*	Pycnonotidae	A	LC
120	White-throated Bulbul	*Alophoixus flaveolus*	Pycnonotidae	O	LC
121	Black Bulbul	*Hypsipetes leucocephalus*	Pycnonotidae	C	LC
122	Ashy Bulbul	*Hemixos flavala*	Pycnonotidae	C	LC
123	Mountain Bulbul	*Ixos mcclellandii*	Pycnonotidae	O	LC
124	Chestnut-headed Tesia	*Cettia castaneocoronata*	Cettiidae	C	LC
125	Black-faced Warbler	*Abroscopus schisticeps*	Cettiidae	O	LC
126	Brownish-flanked Bush Warbler	*Horornis fortipes*	Cettiidae	O	LC
127	Aberrant Bush Warbler	*Horornis flavolivaceus*	Cettiidae	O	LC
128	Dusky Warbler	*Phylloscopus fuscatus*	Cettiidae	O	LC
129	Hume's Bush warbler	*Cettia brunnescens*	Cettiidae	O	LC
130	Tickell's Leaf Warbler	*Phylloscopus affinis*	Cettiidae	C	LC
131	Ashy-throated Warbler	*Phylloscopus maculipennis*	Cettiidae	O	LC
132	Yellow-browed Warbler	*Phylloscopus inornatus*	Cettiidae	O	LC
133	Smoky Warbler	*Phylloscopus fuliventer*	Phylloscopidae	O	LC
134	Greenish Warbler	*Phylloscopus trochiloides*	Phylloscopidae	O	LC

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135	Western Crowned Warbler	*Phylloscopus occipital*	Phylloscopidae	O	LC
136	Yellow-vented Warbler	*Phylloscopus cantator*	Phylloscopidae	O	LC
137	Gray-hooded Warbler	*Phylloscopus xanthoschistos*	Phylloscopidae	C	LC
138	Golden-spectacled Warbler	*Seicercus burkii*	Phylloscopidae	O	LC
139	Whistler's Warbler	*Seicercus whistleri*	Phylloscopidae	O	LC
140	White-spectacled Warbler	*Seicercus affinis*	Phylloscopidae	O	LC
141	Chestnut-crowned Warbler	*Seicercus castaniceps*	Phylloscopidae	O	LC
142	Pale-rumped warbler	*Phylloscopus chloronotus*	Phylloscopidae	O	LC
143	Brown Bush Warbler	*Locustella luteoventris*	Locustellidae	O	LC
144	Common Tailorbird	*Orthotomus sutorius*	Cisticolidae	C	LC
145	Striated Prinia	*Prinia crinigera*	Cisticolidae	O	LC
146	Rufescent Prinia	*Prinia rufescens*	Cisticolidae	O	LC
147	Grey-breasted Prinia	*Prinia hodgsonii*	Cisticolidae	O	LC
148	Jungle Prinia	*Prinia sylvatica*	Cisticolidae	O	LC
149	White-browed Fulvetta	*Fulvetta vinipectus*	Slyviidae	O	LC
150	Greater Rufous-headed Parrotbill	*Psittiparus bakeri*	Slyviidae	O	LC
151	Lesser Rufous-headed Parrotbill	*Chleuasicus atrosuperciliaris*	Slyviidae	O	LC
152	Striated Yuhina	*Yuhina castaniceps*	Zosteropidae	O	LC
153	Stripe-throated Yuhina	*Yuhina gularis*	Zosteropidae	O	LC
154	Whiskered Yuhina	*Yuhina flavicollis*	Zosteropidae	C	LC
155	Rufous-vented Yuhina	*Yuhina occipitalis*	Zosteropidae	O	LC
156	Black-chinned Yuhina	*Yuhina nigrimenta*	Zosteropidae	O	LC
157	Oriental (Indian) White-eye	*Zosterops palpebrosus*	Zosteropidae	C	LC
158	Rufous-vented Yuhina	*Yuhina occipitalis*	Zosteropidae	O	LC
159	Puff-throated Babbler	*Pellorneum ruficeps*	Pellorneidae	O	LC
160	Golden Babbler	*Cyanoderma chrysaeum*	Timaliidae	R	LC
161	Rufous-capped Babbler	*Cyanoderma ruficeps*	Timaliidae	O	LC
162	White-browed Scimitar-babbler	*Pomatorhinus schisticeps*	Timaliidae	O	LC
163	Rusty-cheeked Scimitar-babbler	*Megapomatorhinus erythrogenys*	Timaliidae	C	LC
164	Coral-billed Scimitar-babbler	*Pomatorhinus ferruginosus*	Timaliidae	R	LC
165	Streak-breasted Scimitar-babbler	*Pomatorhinus ruficollis*	Timaliidae	R	LC
166	Gray-throated Babbler	*Stachyris nigriceps*	Timaliidae	O	LC
167	Scaly-breasted Wren-babbler	*Pnoepyga albiventer*	Pnoepygidae	R	LC
168	Long-billed Wren-babbler	*Rimator malacoptilus*	Pellorneidae	R	LC
169	Yellow-throated Fulvetta	*Schoeniparus cinereus*	Pellorneidae	O	LC
170	Rufous-winged Fulvetta	*Schoeniparus castaneceps*	Pellorneidae	O	LC
171	Nepal Fulvetta	*Alcippe nipalensis*	Pellorneidae	O	LC
172	Striated Laughingthrush	*Grammatoptila striata*	Leiothrichidae	C	LC
173	White-crested Laughingthrush	*Garrulax leucolophus*	Leiothrichidae	A	LC
174	Lesser Necklaced Laughingthrush	*Garrulax monileger*	Leiothrichidae	O	LC
175	White-throated Laughingthrush	*Pterorhinus albogularis*	Leiothrichidae	O	LC
176	Grey-sided Laughingthrush	*Pterorhinus caerulatus*	Leiothrichidae	R	LC
177	Bhutan Laughingthrush	*Trochalopteron imbricatum*	Leiothrichidae	O	LC
178	Blue-winged Laughingthrush	*Trochalopteron squamatum*	Leiothrichidae	O	LC
179	Chestnut-crowned Laughingthrush	*Trochalopteron erythrocephalum*	Leiothrichidae	O	LC

	Common name	Scientific name	Family	Categorization	IUCN Red List status
180	Rufous-chinned Laughing Thrush	*Ianthocincla rufogularis*	Leiothrichidae	O	LC
181	Rufous Sibia	*Heterophasia capistrata*	Leiothrichidae	C	LC
182	Silver-eared Mesia	*Leiothrix argentauris*	Leiothrichidae	C	LC
183	Red-billed Leiothrix	*Leiothrix lutea*	Leiothrichidae	C	LC
184	Red-tailed Minla	*Minla ignotincta*	Leiothrichidae	C	LC
185	Rusty-fronted Barwing	*Actinodura egertoni*	Leiothrichidae	C	LC
186	Blue-winged Minla	*Actinodura cyanouroptera*	Leiothrichidae	C	LC
187	Chestnut-tailed Minla	*Actinodura strigula*	Leiothrichidae	O	LC
188	Long-tailed Sibia	*Heterophasiapicaoides*	Leiothrichidae	R	LC
189	Red-faced Liocichla	*Liocichla phoenicea*	Leiothrichidae	O	LC
190	Asian Brown Flycatcher	*Muscicapa dauurica*	Muscicapidae	O	LC
191	Dark-sided Flycatcher	*Muscicapa sibirica*	Muscicapidae	O	LC
192	Slaty-backed Flycatcher	*Ficedula erithacus*	Muscicapidae	O	LC
193	Ferruginous Flycatcher	*Muscicapa ferruginea*	Muscicapidae	R	LC
194	Oriental Magpie-Robin	*Copsychus saularis*	Muscicapidae	A	LC
195	Blue-throated Flycatcher	*Cyornis rubeculoides*	Muscicapidae	O	LC
196	Large Niltava	*Niltava grandis*	Muscicapidae	O	LC
197	Small Niltava	*Niltava macgrigoriae*	Muscicapidae	O	LC
198	Rufous-bellied Niltava	*Niltava sundara*	Muscicapidae	O	LC
199	Verditer Flycatcher	*Eumyias thalassinus*	Muscicapidae	C	LC
200	Pale Blue Flycatcher	*Cyornis unicolor*	Muscicapidae	R	LC
201	Blue Whistling-Thrush	*Myophonus caeruleus*	Muscicapidae	A	LC
202	Spotted Forktail	*Enicurus maculatus*	Muscicapidae	O	LC
203	Slaty-backed Forktail	*Enicurus schistaceus*	Muscicapidae	C	LC
204	Siberian Rubythroat	*Calliope calliope*	Muscicapidae	R	LC
205	Himalayan Bluetail	*Tarsiger rufilatus*	Muscicapidae	O	LC
206	Indian Bush Robin	*Larvivora brunnea*	Muscicapidae	R	LC
207	Rufous-breasted Bush-Robin	*Tarsiger hyperythrus*	Muscicapidae	R	LC
208	Slaty-blue Flycatcher	*Ficedula tricolor*	Muscicapidae	O	LC
209	Rufous-gorgeted Flycatcher	*Ficedula strophiata*	Muscicapidae	O	LC
210	Sapphire Flycatcher	*Ficedula sapphira*	Muscicapidae	R	LC
211	Little Pied Flycatcher	*Ficedula westermanni*	Muscicapidae	O	LC
212	Ultramarine Flycatcher	*Ficedula superciliaris*	Muscicapidae	O	LC
213	Taiga Flycatcher	*Ficedula albicilla*	Muscicapidae	O	LC
214	Red-breasted Flycatcher	*Ficedula parva*	Muscicapidae	R	LC
215	Blue-fronted Redstart	*Phoenicurus frontalis*	Muscicapidae	O	LC
216	Plumbeous Redstart	*Phoenicurus fuliginosus*	Muscicapidae	C	LC
217	White-capped Redstart	*Phoenicurus leucocephalus*	Muscicapidae	C	LC
218	Hodgson's Redstart	*Phoenicurus hodgsoni*	Muscicapidae	O	LC
219	Black Redstart	*Phoenicurus ochruros*	Muscicapidae	R	LC
220	White-winged Redstart	*Phoenicurus erythrogastrus*	Muscicapidae	R	LC
221	Chestnut-bellied Rock-Thrush	*Monticola rufiventris*	Muscicapidae	O	LC
222	Blue-capped Rock-Thrush	*Monticola cinclorhynchus*	Muscicapidae	O	LC
223	Blue Rock-Thrush	*Monticola solitaries*	Muscicapidae	O	LC
224	Siberian Stonechat	*Saxicola maurus*	Muscicapidae	O	LC

	Common name	Scientific name	Family	Categorization	IUCN Red List status
225	Grey Bushchat	*Saxicola ferreus*	Muscicapidae	C	LC
226	Lesser Shortwing	*Brachypteryx leucophris*	Muscicapidae	R	LC
227	Eye-browed Thrush	*Turdus obscurus*	Turdidae	R	LC
228	Orange-headed Thrush	*Geokichla citrina*	Turdidae	O	LC
229	Tickell's Thrush	*Turdus unicolor*	Turdidae	C	LC
230	Gray-winged Blackbird	*Turdus boulboul*	Turdidae	O	LC
231	Black-throated Thrush	*Turdus atrogularis*	Turdidae	O	LC
232	Scaly Thrush	*Zoothera dauma*	Turdidae	O	LC
233	Chestnut-tailed Starling	*Sturnia malabarica*	Sturnidae	C	LC
234	Common Myna	*Acridotheres tristis*	Sturnidae	A	LC
235	Great Myna	*Acridotheres grandis*	Sturnidae	O	LC
236	Golden-fronted Leafbird	*Chloropsis aurifrons*	Chloropseidae	O	LC
237	Orange-bellied Leafbird	*Chloropsis hardwickii*	Chloropseidae	O	LC
238	Fire-breasted Flowerpecker	*Dicaeum ignipectus*	Dicaeidae	C	LC
239	Black-throated Sunbird	*Aethopyga saturate*	Nectariniidae	O	LC
240	Green-tailed Sunbird	*Aethopyga nipalensis*	Nectariniidae	C	LC
241	Crimson Sunbird	*Aethopyga siparaja*	Nectariniidae	C	LC
242	Streaked Spiderhunter	*Arachnothera magna*	Nectariniidae	C	LC
243	Rufous-breasted Accentor	*Prunella strophiata*	Prunellidae	O	LC
244	Grey Wagtail	*Motacilla cinerea*	Motacillidae	C	LC
245	White Wagtail	*Motacilla alba*	Motacillidae	C	LC
246	White browed Wagtail	*Motacilla madraspatensis*	Motacillidae	O	LC
247	Olive-backed Pipit	*Anthus hodgsoni*	Motacillidae	A	LC
248	Crested Bunting	*Melophus lathami*	Emberizidae	O	LC
249	Yellow-breasted Greenfinch	*Chloris spinoides*	Fringillidae	O	LC
250	Tibetan Serin	*Spinus thibetanus*	Fringillidae	R	LC
251	Common Rosefinch	*Carpodacus erythrinus*	Fringillidae	O	LC
252	House Sparrow	*Passer domesticus*	Passeridae	O	LC
253	Russet Sparrow	*Passer rutilans*	Passeridae	C	LC
254	Eurasian Tree Sparrow	*Passer montanus*	Passeridae	A	LC
255	White-rumped Munia	*Lonchura striata*	Estrildidae	O	LC
256	Scaly-breasted Munia	*Lonchura punctulata*	Estrildidae	C	LC
257	Plum-headed Parakeet	*Psittaculacyanocephala*	Psittaculidae	R	LC
258	Slaty-headed Parakeet	*Psittacula Himalayana*	*Psittaculidae*	R	LC

LC—Least Concern | VU—Vulnerable | A—Abundant | C—Common | O—Occasional | R—Rare | NE—Not Evaluated.

CONCLUSION AND RECOMMENDATIONS

This study represents one of the few documented references of bird inventory in the region and can be used as baseline data for future monitoring and survey. The comprehensive bird checklist indicates, that some areas lying outside protected areas in Bhutan provide good habitats for birds. However, the current trend of anthropogenic activities such as timber felling, new farm road construction, and increased resource collections due to fewer restrictions as opposed to within protected areas pose a significant threat to birds.

Since this study was limited to a checklist, there are opportunities for in-depth studies on birds' interaction with ecosystems and associated threats in order to encourage bird conservation in the area. Further, a systematic study is recommended covering the whole of the Tsirang Forest area jurisdiction as we could only cover the areas below 2,500 m.

Similar studies are suggested in other areas contiguous to protected areas in Bhutan as well as in the region. This should aid an understanding of the factors driving the differences in bird diversity within and outside the protected areas in Bhutan and should help in initiating conservation actions in future.

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Image 3–17. 3—*Andea Insignis* | 4—*Zosterops palpebrosus* | 5—*Aegithina tiphia* | 6—*Parus monticolus* | 7—*Aceros nipalensis* | 8—*Buceros bicornis* | 9—*Psilopogon asaticus* | 10—*Trochalopteron erythocephalum* | 11—*Turdus atrogularis* (F) | 12—*Myophonus caeruleus* | 13—*Monticola rufriventris* | 14—*Niltava macgrigoriae* (F) | 15—*Passer rutilans* | 16—*Passer montanus* | 17—*Spilopelia chinensis.* © Gyeltshen.

Image 18–32. 18—*Lanius tephronotus* | 19—*Columba livia* | 20—*Harpactes erythrocephalus* | 21—*Ducula badia* | 22—*Arborophila rufogularis* | 23—*Chloropsis hardwickii* (F) | 24—*Alophoixus flaveolus* | 25—*Sasia ochracea* | 26—*Upupa epops* | 27—*Moticilla alba* | 28—*Rhyacornis Fuliginosa* | 29—*Megaceryle lugubris* | 30—*Otus spilocephalus* | 31—*Halcyon smyrnensis* | 32—*Phoenicurus ochruros.* © Gyeltshen.

Image 33–47. 33—*Dendrocitta formosae* | 34—*Cuculus canorus* | 35—*Passer domesticus* (F) | 36—*Geokichla citrina* | 37—*Hemixos flavala* | 38—*Lophotriochis kienerii* (Juv) | 39—*Picumnus innominatus* | 40—*Erpornis zantholeuca* (Juv) | 41—*Sexicola ferreus* (M) | 42—*Cecropis daurica* | 43—*Megalaima franklinii* | 44—*Yuhina gularis* | 45—*Ficedula tricolor* (M) | 46—*Niltava sundar*a | 47—*Ficedula hodgsonii.* © Gyeltshen.

Image 48–61. 48—*Lonchura punctulata* | 49—*Glaucidium brodiei* | 50—*Eumyias thalassinus* | 51—*Sturnia malab* | 52—*Acridotheres tristis* | 53—*Acridotheres grandis* | 54—*Brachypteryx leucophris* | 55—*Rimator malacoptilus* | 56—*Accipiter virgatus* | 57—*Horornis fortipes* | 58—*Ficedula hypoleuca* | 59—*Psittiparus gularis* | 60—*Hierococcyx sparverioides* | 61—*Psittacula cyanocephala*. © Sonam Dorji (images 54–55), rest of the images © Gyeltshen.

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COMMUNICATION

Importance of conserving a critical wintering ground for shorebirds in the Valinokkam Lagoon—a first study of the avifaunal distribution of the southeastern coast of India

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Abstract: Any new economic activity in a virgin area brings landscape changes, making it essential to document baseline biodiversity areas to understand the impacts on habitats. Avifaunal inventories are critical for previously undocumented areas like the Valinokkam Lagoon in the Ramanathapuram District of Tamil Nadu, which is an undocumented wintering site for shorebirds in the Central Asain Flyway (CAF). To formulate site and species-specific conservation management tools, the first bird baseline recorded 154 species of 16 orders and 46 families from August 2016 to February 2023. Order-wise, Charadriiformes (47 species) dominated the study area, followed by Passeriformes (39 species) and Pelecaniformes (20 species). Furthermore, according to the IUCN Red List Category, 11 Near Threatened (NT) species, one Endangered (EN) species (Great Knot *Calidris tenuirostris),* and one unassessed Hanuman Plover (*Charadrius seebohmi*) were recorded. The relative abundance indicated that 61 % (94 species) were Common (C), 26.6% (41 species) were uncommon (UC), and 12.3 % (19 species) were rare (Ra). Based on the residential status, winter visitors constituted 37.6 % (58 species) and one Passage Migrant (Rosy Starling *Pastor roseus*). This baseline data emphasizes the importance of Valinokkam Lagoon as a crucial wintering site in the CAF on the southeastern coast of India for migratory shorebirds and the need for more conservation priorities for regional endemic birds like Hanuman Plover.

Keywords: Bird migration, Central Asian Flyway, Gulf of Mannar, Hanuman Plover breeding, over summering, waterbirds, winter visitors.

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INTRODUCTION

The documentation on avifaunal diversity and distribution is widely done in India (Ali & Ripley 1987; Rasmussen & Anderton 2005) and has helped to assess long-term landscape changes, ecological assessments, and conservation planning (Kati & Sekercioglu 2006), leading to new management ingenuities (Paul & Cooper 2005). The bird community structure of any area helps in understanding how the landscape changes over time (Kattan & Franco 2004). As a fast-growing economy, the country's push for economic development for population demand is ever-increasing, leading to landscape changes impacting the new virgin areas (Jha et al. 2000; Purvis & Hector 2000; Velenturf & Purnell 2021). Hence, there is a consistent need for monitoring new potential bird areas. For long-term management approaches, local bird monitoring is critical (Gadgil 1996), and baseline knowledge is fundamental (Peterson et al. 2000; Llanos et al. 2011). This helps in understanding the costs of habitation loss, dilapidation, and climate change (Llanos et al. 2011).

The southeast coast of India forms an important path in the Indian subcontinent of the CAF (Balachandran 2006; Sangha 2021), which is the shortest flyway among the migratory pathways (Stroud et al. 2006). Previous studies on the east coast of India revealed the declining trend of shorebird populations and their habitats (Sandilyan et al. 2010; Kannan & Pandiyan 2012; Rashiba et al. 2022; Byju et al. 2023a). The Gulf of Mannar Marine Biosphere Park (GoM) serves as a significant link for both migratory and resident shorebirds on the southeastern coast of India, along with the other Important Bird Areas (IBA) like Chilika Lake in Odisha, Pulicat Lake in Andhra Pradesh, and Point Calimere in Tamil Nadu (Balachandran 2006). Due to its geographical proximity to Sri Lanka, GoM is an important stopover site in the CAF for migratory waterbirds and passerines (Islam & Rahmani 2004). On the Sri Lankan side, there are four IBAs (Anatidal-Thondamannar, Araly South-Punale, Kaithady, and Kayts Island-Mandativu) in the Jaffna District about 10 km away (Anonymous 2003) and has recorded 315 avian species (Birdlife Internatonal 2022) including migratory shorebirds that migrate annually from the northern autumn-winter to the tropics along the CAF (Warakagoda & Sirivardana 2011) with the adjacent Indian mainland (Rasmussen 2005).

Ramanathapuram District of Tamil Nadu holds five bird sanctuaries, including two Ramsar sites and the GoM. Recently, sightings of Artic Skua *Stercorarius parasiticus* (Byju & Raveendran 2022a) and an unusual record of Light-mantled Albatross *Phoebetria palpebrata* (Byju & Raveendran 2022b) from the district highlight the need for continuous monitoring of birds in the rapidly depleting environment and the need of baseline surveys of populations from new extents. Updated avifaunal details from the district have been reported from the 21 islands of GoM (Byju et al. 2023a) and a new wintering site in Karangadu mangroves (Byju et al. 2023b). The intensive and continuous monitoring of shorebirds also revealed three breeding locations of newly elevated taxa Hanuman Plover *Charadrius seebohmi* from the subspecies *Charadrius alexandrinus seebohmi* (Niroshan et al. 2023) in the district (Byju et al. 2023c), which includes the present study site. These findings emphasize the need for baseline data from unexplored areas to help classify areas of conservation significance. This groundwork emphasizes the need to conserve this critical shorebird wintering site in the CAF and suggests elevating this site to protected status.

MATERIALS AND METHODS

Study Area

Valinokkam Lagoon (9.1661 °N, 78.6141 °E) is situated on the southeast coast of India, in the Kadaladi Taluk of Ramanathapuram District in Tamil Nadu. The lagoon is approximately 10.12 km long with an area of 1,145.84 ha and the salt pan adjacent to it constitutes around 1,197.34 ha (Figure 1). Invasive *Prosopis juliflora* and Palmyra Palm *Borassus flabellifer* trees surround the lagoon providing a habitat for a variety of land birds. The State Salt Corporation pumps extra water from the sea and stores in bunds for salt extraction forming a man-made lagoon. This region gradually transformed into a mudflat that was home to several species of birds. The salt pans which continuously harvest salt, contribute to the regular presence of birds in the study site. Fishing activities and prawn culture are found only during a few months when the water is plentiful. Along the edges of the lagoons halophytes can also be seen.

Bird survey method

In Valinokkam Lagoon, bird surveys were done from August 2016 to March 2019 and from August 2020 to February 2023. In the other periods mentioned, incidental bird records were collected through opportunistic encounters. The birds were observed during the peak hours of their activity, from 0600–1000 h and 1600–1800

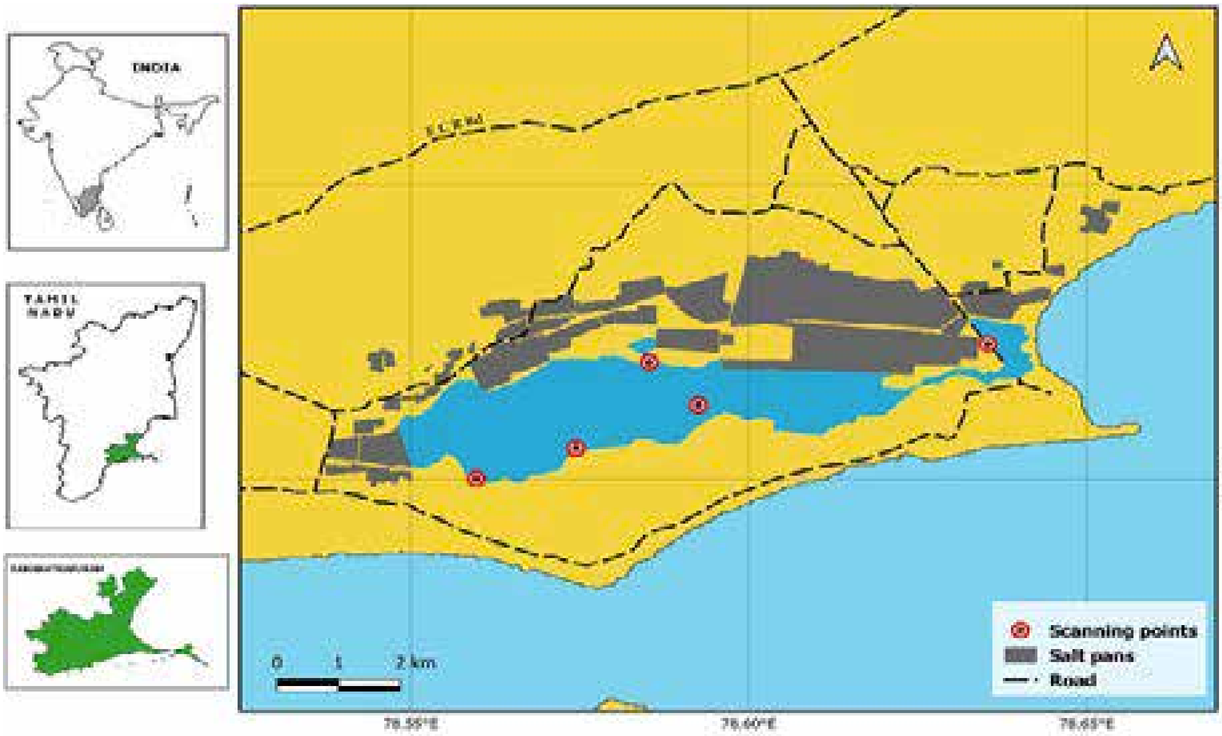

Figure 1. Map of Valinokkam Lagoon with scanning points and the adjacent salt pans.

h. Later, bird surveys were conducted using block count and direct visual count methods (Howes & Bakewell 1989; Bibby et al. 2000). In this method, five scanning points were identified based on the water availability throughout the year and the congregation with a varying distance of 600–1,500 m (Figure 1), and birds in the blocks were observed using Nikon binoculars (10 x 50) and photographed with a Canon 100–400 mm lens and identified with the help of field guides (Grimmett et al. 2011; Hayman et al. 2011). Since this is a man-made lagoon no impact of tides were there for the study. Bird counting started after five minutes at each scanning point to allow the waterbirds to settle down to the human presence. The observations recorded while moving from one scanning point to another were entered as incidental records. The residential status of the birds were grouped under different categories like Resident (R), Resident/ Not Breeding (R/NB)), Passage Migrant (PM), and Winter Visitor (WV) depending on their timing and duration of occurrence (Grimmett et al. 2011). The common name, scientific name, IUCN Red List status, and migratory status are followed (Praveen & Jayapal 2023). With regard to MacKinnon & Phillipps (1993), data were later analyzed for relative abundance based on the number of sightings: common (C) sighted seven to nine times; uncommon (UC) sighted three to six times; rare (Ra) sighted once or twice.

RESULTS AND DISCUSSIONS

Avifauna structure

A total of 154 species of birds belonging to 46 families under 16 orders were recorded from the Valinokkam Lagoon (Table 1) (Image 1–10). Order-wise, Charadriiformes dominated the study site with 47 species, followed by Passeriformes (39 species) and Pelecaniformes (20 species), with the lowest being Pheonicopteriformes, Caprimulgiformes, Bucerotiformes, and Psittaciformes sharing one species each (Figure 2). The highest number of bird species was found to be represented by the family Scolopacidae (22 species), followed by Laridae (12 species), Ardeidae (10 species), Anatidae (nine species) and Charadriidae (nine species) (Figure 3).

The residential status of the birds was: winter visitors (WV) constituted 37.6% (58 species) and one passage migrant (PM) Rosy Starling *Pastor roseus*. The relative abundance indicated that (61%) 94 species were common, 26.6% (41 species) were uncommon, and (12.3%) 19 species were rare. Eleven 'Near Threatened' (NT) species: Bar-tailed Godwit *Limosa lapponica,* Black-headed Ibis *Threskiornis melanocephalus,* Black-tailed Godwit *Limosa limosa*, Curlew Sandpiper *Calidris ferruginea,* Eurasian Curlew *Numenius arquata,* Great Stone-curlew *Esacus recurvirostris*, Oriental

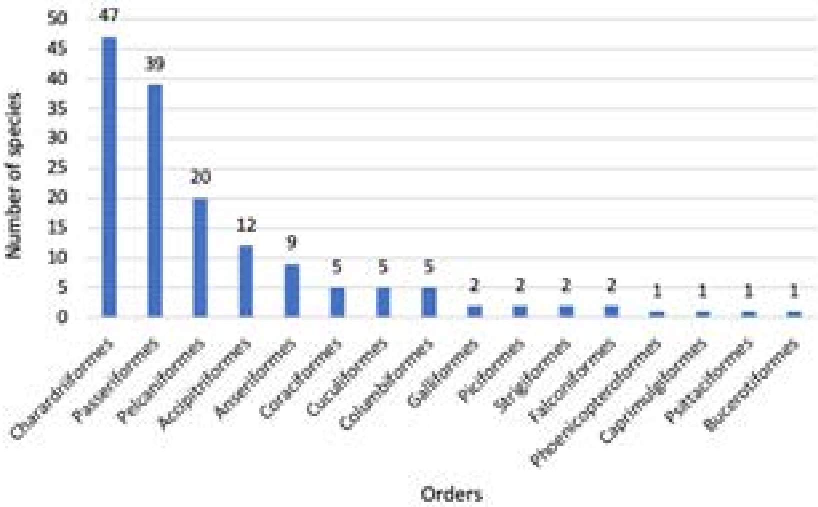

Figure 2. Order-wise representation of bird species at Valinokkam Lagoon.

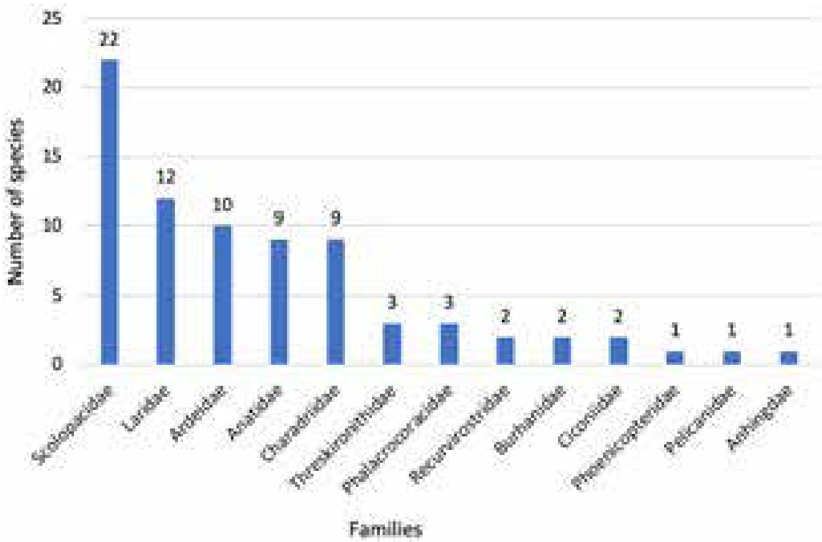

Figure 3. Family-wise representation of waterbirds at Valinokkam Lagoon.

Darter *Anhinga melanogaster*, Painted Stork *Mycteria leucocephala*, Red-necked Stint *Calidris ruficollis,* Red Knot *Calidris canutus,* Spot-billed Pelican *Pelecanus philippensis,* one 'Endangered' (EN) Great Knot *Calidris tenuirostris*, one unassessed Hanuman Plover *Charadrius seebohmi,* and the rest of 141 were of 'Least Concern' (LC) according to the IUCN Red List category.

Valinokkam is a crucial wintering site on the southeastern coast

Tamil Nadu is home to 535 bird species according to Praveen & Jayapal (2023), and Valinokkam recorded 154 species (28.78%). A total of 77 waterbird species reported from this study site, including 35 species of shorebirds, 21 species of large wading birds, nine species of ducks, four species of gulls, and eight species of terns. Six of the nine duck species were winter visitors: Common Teal *Anas crecca*, Bar-headed Goose *Anser indicus*, Greylag Goose *Anser anser*, Garganey *Spatula querquedula,* Northern Shoveler *Spatula clypeata*, and Northern Pintail *Anas acuta*, and the remaining three were residents/not breeding (R/NB) in the area: Knob-billed Duck *Sarkidiornis melanotos*, Indian Spot-billed Duck *Anas poecilorhyncha*, and Lesser Whistling Duck *Dendrocygna javanica*. Except for the Northern Pintail, which was rare, all the other taxa were uncommon among the ducks.

Among the 21 species of large wading birds, including

Table 1. Avifaunal checklist of Valinokkam Lagoon, Ramanathapuram, Tamil Nadu, India.

	Order/Family/Common name	Scientific name	IUCN Red List status	Resident status	Relative abundance
	Anseriformes: Anatidae				
1	Knob-billed Duck	*Sarkidiornis melanotos*	LC	R/NB	UC
2	Common Teal	*Anas crecca*	LC	WV	UC
3	Bar-headed Goose	*Anser indicus*	LC	WV	UC
4	Greylag Goose	*Anser anser*	LC	WV	UC
5	Garganey	*Spatula querquedula*	LC	WV	UC
6	Northern Shoveler	*Spatula clypeata*	LC	WV	UC
7	Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	R/NB	UC
8	Lesser Whistling Duck	*Dendrocygna javanica*	LC	R/NB	UC
9	Northern Pintail	*Anas acuta*	LC	WV	Ra
	Phoenicopteriformes: Phoenicopteridae				
10	Greater Flamingo	*Phoenicopterus roseus*	LC	R/NB	C
	Columbiformes: Columbidae				
11	Rock Pigeon	*Columba livia*	LC	R	C
12	Spotted Dove	*Spilopelia chinensis*	LC	R	C
13	Eurasian collared Dove	*Streptopelia decaocto*	LC	R	C
14	Laughing Dove	*Spilopelia senegalensis*	LC	R	C
15	Red Collared Dove	*Streptopella tranquebarica*	LC	R	UC
	Caprimulgiformes: Apodidae				
16	Asian Palm Swift	*Cypsiurus balasiensis*	LC	R	C
	Cuculiformes: Cuculidae				
17	Asian Koel	*Eudynamys scolopaceus*	LC	R	C
18	Common Hawk Cuckoo	*Hierococcyx varius*	LC	R	Ra
19	Greater Coucal	*Centropus sinensis*	LC	R	C
20	Blue-faced Malkoha	*Phaenicophaeus viridirostris*	LC	R	C
21	Pied Cuckoo	*Clamator jacobinus*	LC	R/NB	C
	Galliformes: Phasianidae				
22	Grey Francolin	*Ortygornis pondicerianus*	LC	R	C
23	Indian Peafowl	*Pavo cristatus*	LC	R	C
	Pelecaniformes: Ciconiidae				
24	Asian Openbill Stork	*Anastomus oscitans*	LC	R/NB	C
25	Painted Stork	*Mycteria leucocephala*	NT	R/NB	C
	Pelecanidae				
26	Spot-billed Pelican	*Pelecanus philippensis*	NT	R/NB	C
	Ardeidae				
27	Black-crowned Night Heron	*Nycticorax nycticorax*	LC	R/NB	C
28	Cattle Egret	*Bubulcus ibis*	LC	R/NB	C
29	Purple Heron	*Ardea purpurea*	LC	R/NB	UC
30	Grey Heron	*Ardea cinerea*	LC	R/NB	C
31	Indian Pond Heron	*Ardeola grayii*	LC	R/NB	C
32	Intermediate Egret	*Ardea intermedia*	LC	R/NB	C
33	Great Egret	*Ardea alba*	LC	R/NB	C
34	Little Egret	*Egretta garzetta*	LC	R/NB	C

	Order/Family/Common name	Scientific name	IUCN Red List status	Resident status	Relative abundance
35	Striated Heron	*Butorides striata*	LC	R/NB	C
36	Western Reef Egret	*Egretta gularis*	LC	LM	UC
	Threskiornithidae				
37	Black-headed Ibis	*Threskiornis melanocephalus*	NT	R/NB	C
38	Eurasian Spoonbill	*Platalea leucorodia*	LC	R/NB	C
39	Glossy Ibis	*Plegadis falcinellus*	LC	R/NB	C
	Phalacrocoracidae				
40	Great Cormorant	*Phalacrocorax carbo*	LC	R/NB	UC
41	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	R/NB	C
42	Little Cormorant	*Microcarbo niger*	LC	R/NB	C
	Anhingidae				
43	Oriental Darter	*Anhinga melanogaster*	NT	R/NB	UC
	Charadriiformes: Recurvirostridae				
44	Black-winged Stilt	*Himantopus himantopus*	LC	R	C
45	Pied Avocet	*Recurvirostra avosetta*	LC	WV	Ra
	Burhinidae				
46	Indian Stone-Curlew	*Burhinus indicus*	LC	R	C
47	Great Stone-Curlew	*Esacus recurvirostris*	NT	R	UC
	Charadriidae				
48	Black-bellied Plover	*Pluvialis squatarola*	LC	WV	C
49	Pacific Golden Plover	*Pluvialis fulva*	LC	WV	Ra
50	Lesser Sand Plover	*Charadrius mongolus*	LC	WV	C
51	Greater Sand Plover	*Charadrius leschenaultii*	LC	WV	C
52	Kentish Plover	*Charadrius alexandrinus*	LC	WV	C
53	Common Ringed Plover	*Charadrius hiaticula*	LC	WV	UC
54	Hanuman Plover	*Charadrius seebohmi*	NA	R	C
55	Little Ringed Plover	*Charadrius dubius*	LC	WV	C
56	Red-wattled Lapwing	*Vanellus indicus*	LC	R	C
	Scolopacidae				
57	Black-tailed Godwit	*Limosa limosa*	NT	WV	UC
58	Bar-tailed Godwit	*Limosa lapponica*	NT	WV	UC
59	Whimbrel	*Numenius phaeopus*	LC	WV	C
60	Eurasian Curlew	*Numenius arquata*	NT	WV	C
61	Temminck's Stint	*Calidris temminckii*	LC	WV	UC
62	Little Stint	*Calidris minuta*	LC	WV	C
63	Ruff	*Calidris pugnax*	LC	WV	UC
64	Curlew Sandpiper	*Calidris ferruginea*	NT	WV	C
65	Dunlin	*Calidris alpina*	LC	WV	Ra
66	Red necked Stint	*Calidris ruficollis*	NT	WV	Ra
67	Common Sandpiper	*Actitis hypoleucos*	LC	WV	UC
68	Ruddy Turnstone	*Arenaria interpres*	LC	WV	C
69	Green Sandpiper	*Tringa ochropus*	LC	WV	C
70	Marsh Sandpiper	*Tringa stagnatilis*	LC	WV	UC
71	Wood Sandpiper	*Tringa glareola*	LC	WV	UC
72	Common Greenshank	*Tringa nebularia*	LC	WV	C

	Order/Family/Common name	Scientific name	IUCN Red List status	Resident status	Relative abundance
73	Common Redshank	*Tringa totanus*	LC	WV	C
74	Terek Sandpiper	*Xenus cinereus*	LC	WV	C
75	Sanderling	*Calidris alba*	LC	WV	UC
76	Great Knot	*Calidris tenuirostris*	EN	WV	UC
77	Red Knot	*Calidris canutus*	NT	WV	UC
78	Common Snipe	*Gallinago gallinago*	LC	WV	UC
	Laridae				
79	Slender-bill Gull	*Chroicocephalus genei*	LC	WV	UC
80	Black-headed Gull	*Chroicocephalus ridibundus*	LC	WV	C
81	Brown-headed Gull	*Chroicocephalus brunnicephalus*	LC	WV	C
82	Lesser Black-backed Gull	*Larus fuscus*	LC	WV	UC
83	Common Tern	*Sterna hirundo*	LC	WV	UC
84	Little Tern	*Sternula albifrons*	LC	WV	UC
85	Caspian Tern	*Hydroprogne caspia*	LC	WV	C
86	Greater Crested Tern	*Thalasseus bergii*	LC	WV	C
87	Lesser Crested Tern	*Thalasseus bengalensis*	LC	WV	C
88	Sandwich Tern	*Thalasseus sandvicensis*	LC	WV	Ra
89	Gull-billed Tern	*Gelochelidon nilotica*	LC	WV	Ra
90	Whiskered Tern	*Chlidonias hybrida*	LC	WV	Ra
	Accipitriformes: Pandionidae				
91	Osprey	*Pandion haliaetus*	LC	WV	Ra
	Accipitridae				
92	Booted Eagle	*Hieraaetus pennatus*	LC	WV	UC
93	Black Kite	*Milvus migrans*	LC	R	C
94	Black-winged Kite	*Elanus caeruleus*	LC	R	C
95	Brahminy Kite	*Haliastur indus*	LC	R	C
96	Shikra	*Accipiter badius*	LC	R	C
97	Short-toed snake eagle	*Circaetus gallicus*	LC	R	C
98	Eurasian Marsh-Harrier	*Circus aeruginosus*	LC	WV	Ra
99	White-eyed Buzzard	*Butastur teesa*	LC	R	Ra
100	Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	LM	UC
101	European Honey-buzzard	*Pernis apivorus*	LC	WV	Ra
102	White-bellied Sea Eagle	*Haliaeetus leucogaster*	LC	LM	C
	Strigiformes: Strigidae				
103	Spotted Owlet	*Athene brama*	LC	R	C
104	Short eared Owl	*Asio flammeus*	LC	R	UC
	Bucerotiformes: Upupidae				
105	Common Hoopoe	*Upupa epops*	LC	R	C
	Piciformes: Picidae				
106	Black-rumped Flameback	*Dinopium benghalense*	LC	R	C
	Megalaimidae				
107	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	R	C
	Coraciiformes:Meropidae				
108	Blue-tailed Bee-eater	*Merops philippinus*	LC	R	C
109	Green Bee-eater	*Merops orientalis*	LC	R	C

	Order/Family/Common name	Scientific name	IUCN Red List status	Resident status	Relative abundance
	Coraciidae				
110	Indian Roller	*Coracias benghalensis*	LC	R	C
	Alcedinidae				
111	Pied Kingfisher	*Ceryle rudis*	LC	R	C
112	White-throated Kingfisher	*Halcyon smyrnensis*	LC	R	C
	Falconiformes:Falconidae				
113	Peregrine Falcon	*Falco peregrinus*	LC	WV	Ra
114	Eurasian Kestrel	*Falco tinnunculus*	LC	R	C
	Psittaciformes: Psittacidae				
115	Rose-ringed Parakeet	*Psittacula krameri*	LC	R	C
	Passeriformes: Artamidae				
116	Ashy Woodswallow	*Artamus fuscus*	LC	R	C
	Dicruridae				
117	Black Drongo	*Dicrurus macrocercus*	LC	R	C
118	Ashy Drongo	*Dicrurus leucophaeus*	LC	R	UC
	Laniidae				
119	Brown Shrike	*Lanius cristatus*	LC	WV	UC
120	Bay-backed Shrike	*Lanius vittatus*	LC	R	C
	Vangidae				
121	Common Woodshrike	*Tephrodornis pondicerianus*	LC	R	Ra
	Corvidae				
122	House Crow	*Corvus splendens*	LC	R	C
123	Rufous Treepie	*Dendrocitta vagabunda*	LC	R	C
124	Large-billed Crow	*Corvus macrorhynchos*	LC	R	C
	Nectariniidae				
125	Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	R	C
126	Purple Sunbird	*Cinnyris asiaticus*	LC	R	C
	Ploceidae				
127	Baya Weaver	*Ploceus philippinus*	LC	R	C
	Estrildidae				
128	Indian Silverbill	*Euodice malabarica*	LC	R	C
129	Scaly-breasted Munia	*Lonchura punctulata*	LC	R	C
	Passeridae				
130	House Sparrow	*Passer domesticus*	LC	R	C
131	Yellow-throated Sparrow	*Gymnoris xanthocollis*	LC	R	UC
	Motacillidae				
132	Tawny Pipit	*Anthus campestris*	LC	WV	Ra
133	Paddy Field Pipit	*Anthus rufulus*	LC	R	C
134	White-browed Wagtail	*Motacilla maderaspatensis*	LC	R	C
135	Western Yellow Wagtail	*Motacilla flava*	LC	WV	Ra
	Alaudidae				
136	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*	LC	R	C
137	Jerdon's Bushlark	*Mirafra affinis*	LC	R	C
138	Oriental Skylark	*Alauda gulgula*	LC	R	C
139	Sykes's Short-toed Lark	*Calandrella dukhunensis*	LC	WV	UC

	Order/Family/Common name	Scientific name	IUCN Red List status	Resident status	Relative abundance
	Cisticolidae				
140	Common Tailorbird	*Orthotomus sutorius*	LC	R	C
141	Plain Prinia	*Prinia inornata*	LC	R	C
142	Zitting Cisticola	*Cisticola juncidis*	LC	R	C
143	Ashy Prinia	*Prinia socialis*	LC	R	C
	Leiotrichidae				
144	Yellow-billed Babbler	*Argya affinis*	LC	R	C
	Acrocephalidae				
145	Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	R/NB	UC
146	Booted Warbler	*Iduna caligata*	LC	R/NB	Ra
	Hirundinidae				
147	Barn Swallow	*Hirundo rustica*	LC	WV	Ra
148	Red-rumped Swallow	*Cecropis daurica*	LC	R	UC
	Pycnonotidae				
149	Red-vented Bulbul	*Pycnonotus cafer*	LC	R	C
	Sturnidae				
150	Brahminy Starling	*Sturnia pagodarum*	LC	R	UC
151	Common Myna	*Acridotheres tristis*	LC	R	C
152	Rosy Starling	*Pastor roseus*	LC	PM	UC
	Muscicapidae				
153	Indian Robin	*Copsychus fulicatus*	LC	R	C
154	Pied Bushchat	*Saxicola caprata*	LC	R	C

IUCN Red list status: LC—Least Concern | NT—Near Threatened | EN—Endangered |NA: Not assessed | Resident status: WV—Winter Visitor | LM—Local Migrant | R—Resident | R/NB—Resident/Non-Breeding | Relative abundance: C—Common | UC—Uncommon | Ra—Rare.

herons, egrets, and ibises, only one was a local migrant (LM), Western Reef-Heron *Egretta gularis* and the rest were residents/not breeding on the site. Eighteen species were common, three species were uncommon, and two species were rare (Table 1). The most dominant waterbird species identified were Intermediate Egret *Ardea intermedia,* Little Egret *Egreta garzeta* and Indian Cormorant *Phalacrocorax fuscicollis*. Oriental Darter *Anhinga melanogaster*, Black-headed Ibis *Threskiornis melanocephalus*, Painted Stork *Mycteria leucocephala*, and Spot-billed Pelican *Pelecanus philippensis* are the other four waterbirds classified to be Near Threatened. The presence of Greater Flamingo *Phoenicopterus roseus* throughout the year is significant, as there is no breeding record from any nearby known locations on the peninsular India. The populations ranged from 200 to 8,000 individuals through out the period of observation. This also highlights that during December to March the high numbers is due to the arrival of migratory populations, which should be further investigated.

The 35 shorebird species reported included 30 winter visitors, and five species that were nesting locally. The breeding birds include the Indian Stone Curlew *Burhinus indicus*, Great Stone Curlew *Esacus recurvirostris* (one-time peak count of 12), Red-wattled Lapwing *Vanellus indicus*, Black-winged Stilt *Himantopus himantopus*, and the regionally endemic Hanuman Plover. Further, seven species of shorebirds recorded were in the IUCN Red Listed 'Near Threatened' category: Great Stone Curlew, Black-tailed Godwit, Bar-tailed Godwit, Eurasian Curlew, Curlew Sandpiper, Red-necked Stint, and Red Knot, and one species was in the 'Endangered' category—the Great Knot. The Lesser Sand Plover *Charadrius mongolus* (one-time peak count of 4,000) was the most dominant species among the shorebirds recorded, followed by the Little Stint *Calidris minuta* (one-time peak count of 3,000) and the Kentish Plover *Charadrius alexandrinus* (one-time peak count of 2,800).

Apart from the shorebirds and other waterbirds mentioned, four species of gulls, viz., Slender-billed Gull *Chroicocephalus genei*, Black-headed Gull *Chroicocephalus ridibundus,* Brown-headed Gull

Image 1–6. Avifauna of Valinokkkam Lagoon: 1—Greater Flamingoes | 2—Caspian Terns | 3—Small Plovers- Little Stint, Kentish Plover, Lesser Sand Plover and Greater Sand Plover | 4—Shorebirds in front and traditional fishing in the background | 5— Mudflat with shorebirds and salt corporation pump set in the background | 6—Fishing activities in the lagoon.

Image 7–10. Avifauna of Valinokkkam Lagoon 7—Small Plovers with breeding plumage | 8—A flock of Spot bellied Pelican | 9—Sanderling | 10—Hanuman Plover chick

Chroicocephalus brunnicephalus, and Lesser Black-backed Gull *Larus fuscus*, were documented from this site. Of these, the most dominant ones were Black-headed Gull and Brown-headed Gulls. In addition, eight species of terns, viz., Little Tern *Sternula albifrons*, Gull-billed Tern *Gelochelidon nilotica*, Caspian Tern *Hydroprogne caspia*, Whiskered Tern *Chlidonias hybrida*, Common Tern *Sterna hirundo*, Greater Crested Tern *Thalasseus bergii*, Lesser Crested Tern *Thalasseus bengalensis,* and Sandwich Tern *Thalasseus sandvicensis* were also encountered. Through out the research period, Greater Crested Tern was the most prevalent species, followed by the Lesser Crested Tern.

According to Skagen & Knopf (1993), the diversity, abundance, and distribution of shorebirds are determined by the distinctive characteristics of diverse geographical locations, which are influenced by factors such as food availability, substrate character and quality, water quality, and other factors. In this present study, majority of shorebird species were recorded in the study area from late August through May, while other shorebird species were observed in smaller numbers during June and July. Species like Kentish Plover *Charadrius alexandrinus*, Common Redshank *Tringa totanus*, Common Greenshank *Tringa nebularia*, Black-bellied Plover *Pluvialis squatarola*, Curlew Sandpiper *Calidris ferruginea*, Ruddy Turnstone *Arenaria interpres,* Whimbrel *Numenius phaeopus,* Eurasian Curlew *Numenius arquata*, Lesser Sand Plover *Charadrius mongolus*, and Greater Sand Plover *Charadrius leschenaultii* were seen over-summering in most of the study years. We also observed that most of the over-summering birds were either juveniles or sexually unfit. In every year of the study, a few birds over-summed in breeding plumage, like the Kentish Plover, the Black-bellied Plover, the Ruddy Turnstone, and the Curlew Sandpiper (Byju et al. in press). The Lesser Crested Tern and Greater Crested Tern are both found throughout the year. Similarly, several over-summer shorebird species have been reported from Kadalundi Vallikkunnu Community Reserve (KVCR) (Aarif et al. 2020) and Changaram wetlands (Anand et al. 2023). Moreover, due to the periodic pumping of fresh seawater into it for salt extraction in response to the need for salt production, it can be deduced that the food supplies required for over-summering shorebirds are readily accessible throughout the year in this lagoon. Based on the above observations, it is evident that this habitat provides shelter and food resources for over-summering shorebirds.

On the east coast of India, 48 shorebird species have been reported (Sangha 2021). In Valinokkam, we documented 35 species (73%) among them, which explicates the criticality of this wintering site in the CAF for shorebirds. Mudflats on the eastern coast of India recorded higher density, diversity, and richness of shorebirds (Pandiyan & Asokan 2016; Aarif et al. 2021; Rao et al. 2022). The findings of Valinokkam also substantiate these studies, as 35 shorebird species were recorded when compared to 34 at Pulicat Lake (Kannan & Pandiyan 2012). The study of the abundance and spatiotemporal patterns of shorebird populations is necessary to devise management strategies for every ecosystem (Gourley et al. 2010). Therefore, in addition to the previously mentioned areas, it is important to perform extensive investigations to identify all crucial shorebird and stopover sites, seasons, and ecosystems along the Indian coast (Rao et al. 2022). Between breeding and wintering locations, stop-over sites are essential for supporting long-distance migratory shorebirds (Boere et al. 2006). Valinokkam is a critical wintering site since it is close to other significant wintering sites in Karangadu (Byju et al. 2023b), GoM, IBA s of Sri Lanka, and other significant eastern coast shorebird sites within the country on the CAF.

Conservation Significance

We assume that the unscientific removal of *Prosopis juliflora* from the peripheries of the lagoon in the last two years of study had dented the breeding population of Great Stone Curlew and Indian Stone Curlew in the area as we were unable to find the earlier population numbers during the later stages of the study. The breeding of the Short-toed Snake-Eagle *Circaetus gallicus* here on *Prosopis* is another important observation. Recent cutting of *Prosopis juliflora* exposed the lagoon to the public as the access from the nearby roads have become easier. Even though the area had not reported any poaching off late, some activities were reported earlier as per the locals.

Migratory shorebirds adapt to diverse coastal habitats, placing them as a global indicator species for habitat changes (Koskimies 1989; Piersma & Lindstrom 2004). Rashiba et al. (2022) emphasized the steady decline of shorebirds on the Indian east coast, including GoM over the past decade. In the Valinokkam lagoon, pumping sea water for salt production creates artificial wetlands that provide additional habitat for feeding, roosting, and breeding for shorebirds. Saline wetlands are also known to support a diverse array of plant and animal life, which can provide an abundant food source for shorebirds. The traditional salt pans with water storage ponds that form the artificial lagoon for the state salt corporation are shallow and muddy, and the salinity is not much higher than the seawater, which is more used by shorebirds than the actual salt pans that are shallow evaporation ponds. This could be one of the reasons why small shorebirds prefer this site. Similar findings have also been reported from Thailand's salt pans (Isola et al. 2000; Warnock et al. 2002). Salt production companies can work with conservation organizations and researchers to develop management practices that are compatible with maintaining shorebird diversity. This will help balance economic development with environmental protection.

There are several advantages to having a basic avifaunal checklist in an unexplored area. It provides baseline data for identifying areas and species that need conservation and for creating awareness about the importance of birds and their habitats. In addition, it furthers research on the behaviour, ecology, and distribution of the birds. Moreover, it attracts bird watchers and promotes tourism with the help of local communities. The new wintering site in the CAF is also significant, as it helps conservationists develop strategies and take measures to mitigate threats such as habitat loss, pollution, hunting, and disturbance.

CONCLUSION

This pivotal study of a new avifaunal checklist from the wintering site of Valinokkam Lagoon offers crucial baseline data on bird species distribution that aids in the identification of sites with high conservation value and guides conservation and management decisions. Our understanding of the distribution and ecology of bird species can be enhanced by using this information to fill in knowledge gaps. Establishing this preliminary data might serve as foundation basis for tracking bird population changes over time, aiding conservation efforts. This work could also serve as a starting point for further research on habitat use and population dynamics, leading to a deeper understanding of the ecology and conservation needs of bird species, including migratory shorebirds and breeding studies of unassessed Hanuman Plovers from this critical wintering site on the southeast coast of India.

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COMMUNICATION

Diversity and conservation status of avifauna in the Surguja region, Chhattisgarh, India

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Abstract: This study is aimed at updating the avifauna status and to assess major threats in six districts of the Surguja region of northern Chhattisgarh. The avifauna of this region is less studied as compared to the central and southern regions of the state. Chhattisgarh has unique and important habitats for bird species. The geographical region has two major forest types which provide a suitable habitat for many terrestrial and numerous wetlands that support aquatic bird species. The northern region is a basin of rivers Hasdeo and Rihand, prominently forested and a major coal belt. In this study, planned and opportunistic surveys were done in different seasons, and data was collected from 1995 to 2019. In the northern Chhattisgarh region,we have compiled all-district data and a total of 361 bird species were recorded. The maximum number of bird species were recorded from Koriya 318, followed by Raigarh 262, Surguja 162, Balrampur 260, Surajpur 208, and Jashpur 254. Species recorded include three Critically Endangered (CR), two Endangered (EN), five Vulnerable (VU), and 13 Near Threatened (NT). Nesting of Lesser Adjutant, Indian Vulture, White-rumped Vulture, Egyptian Vulture, and sighting of Sarus Crane in Surguja region is reported. The study also revealed the presence of nine Himalayan and sub-Himalayan species. Comparing with previous studies 117 new species were found. Chhattisgarh has ample potential and opportunities for new records as many regions have not yet been adequately explored, it can be a key birding hub for bird lovers as well as the scientific community. The large-scale mining-oriented activities, hunting, and poaching are posing serious threats, which will have a direct or indirect, impact on the future of the avifauna of the region.

Keywords: Birds, checklist, Deccan Peninsula Bio-geographic zone, terrestrial habitats, threats, wetlands.

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INTRODUCTION

The undivided state of Madhya Pradesh prior to year 2000 included the present state of Chhatisgarh and formed a part of central India. Chhattisgarh State has three distinct regions, the northern hills of Surguja, central plains, and Bastar in the south. Surguja is predominantly a hilly extension of the Vindhyachal range landscape with forests and a major coal belt of the state. This region has been a prime hunting ground in the past and supported rich biodiversity. Owing to the large number of existing and upcoming coal mines, railway, and other projects the avifauna are subjected to considerable threat. This study was undertaken to determine the present status of the avifauna, comparing our findings with past studies.

The earlier publications on avifauna of Surguja region are by D'Abreu (1931, 1935) and Hewetson (1956). Ali & Ripley (1987), Grimmett et al. (1998, 2014), Rahmani & Islam (2008), and Rasmussen & Anderton (2012) have included bird records from Surguja region. Other publications are by Chandra & Singh (2004) who recorded 517 species in united Madhya Pradesh. Chakraborty (2008) conducted avifaunal surveys in three protected areas and reported 50 species from Kanger Valley National Park (KVNP), 54 species from Guru Ghasidas National Park (GGNP) of Chhattisgarh, and 44 species from Sanjay Gandhi National Park (SGNP) of Madhya Pradesh.; Chandra & Boaz (2018a) documented 199 species in Surguja District, 230 species in Guru Ghasidas National Park (Chandra & Boaz 2018b), 188 species in Badalkhol Wildlife Sanctuary (Chandra & Boaz 2018c), and 196 species in Gomarda Wildlife Sanctuary (Chandra & Boaz 2018d). In the Surguja region, the status of Malabar Pied Hornbill was reported by Singh & Vishwakarma (2020). Vishwakarma et al. (2020b) documented 133 species at Kopra Reservoir in adjoining Bilaspur District, Chhattisgarh. The intention of the present study was to compare the old and the present avian status, owing to ecological changes caused by the impact of development activities like increase in the number of coal mines, new railway, and power projects. Chhattisgarh Wildlife Society (2009–10) carried out surveys for Indian Peafowl in three protected areas of Chhattisgarh including Raigarh District;52 species at a coal mine in Raigarh District (Anurag Vishwakarma pers. obs. 2018), and 365 species in bird count of Chhattisgarh State including Surguja region (Naidu et al. 2021).

The earlier reports were carried out only partly in the region and the findings were sporadically published. We attempted to cover all districts, even the remotest parts to assess the status of avian species. This study was undertaken to assess the overall avifauna status and conservation issues in the region and to compare old observations of Chakraborty (2008), Chandra & Boaz (2018a,b,c,d) with our observations obtained during the period 1995–2019. An attempt was made to cover as much area as possible by intermittent visits during the period to obtain the best data. This study is helpful in updating avifauna status to some extent, sincemost parts of the region remains unexplored and overall inadequately documented.

STUDY AREA AND METHODS

The Surguja region of Chhattisgarh falls in Chota Nagpur (6B) Province of the Deccan Peninsula Bio-geographic zone of India (Rogers et al. 2002), which extends between southeastern parts of Vindhyachal-Baghelkhand and peninsular region of India. It includes six districts—Koriya, Surguja, Jashpur, Raigarh, Surajpur, and Balrampur—a tablel and of numerous hills and plateaus. The drainage system is mainly through Hasdeo (a tributary of Mahanadi) and Rihand (locally known as Reher, flowing northward) rivers. It has five protected areas including one national park and four wildlife sanctuaries. The Guru Ghasidas National Park, spread over an area of 1,471 km^2 in Koriya District which is also an IBA Site Code (IN-CT-01), was carved out of Sanjay Gandhi National Park of united Madhya Pradesh (Chakraborty 2008). The four wildlife sanctuaries of the Surguja region are i) Badalkhol (104.55 km^2) in Jashpur District, ii) Gomarda (277.91 km^2) in Raigarh District, iii) Semarsot (430.00 km^2) in Surguja District, and iv) Tamor Pingla (608.52 km^2) in Surguja District (Rahmani et al. 2018) covering approximately 18.13% of the total forest area (15,950 km^2) of Surguja region (ENVIS 2015). It has a good expanse of forests, major dams, and extensive territorial agricultural lands and plains. The climate of Surguja is like the rest of Chhattisgarh. The average temperature varies 5–8^{o}C in winter and 40–45^{o}C in summer. The minimum altitude is around 500 m and the highest being 1,226 m at Mailan (Jashpur District) (Chandra & Boaz 2018b).

The main forest typesare mixed deciduous forest (sub classes 3B/C,5A/C, 5B/C, 8A/C, 5/IS1, 3C/C2, 5B/C1) in Surguja District; dry deciduous in Gomarda Wildlife Sanctuary (GWS), Raigarh District; tropical moist deciduous, tropical dry deciduous, Sal and miscellaneous forest in Guru Ghasidas National Park (GGNP) in Koriya and Jashpur districts, and other parts of the region

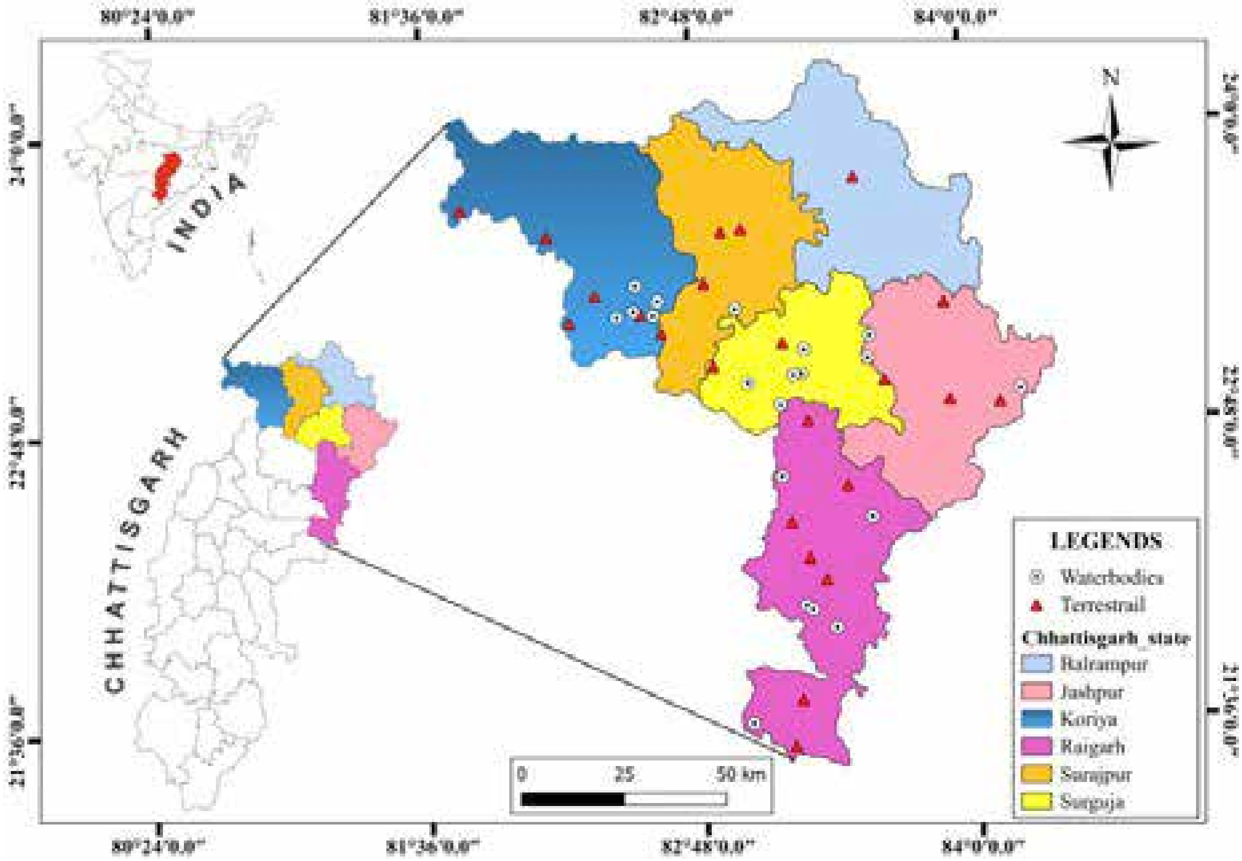

Figure 1. Map showing study site in northern part of Chhattisgarh.

(Champion & Seth 1968; Chandra & Boaz 2018a).

METHODS

This survey covered 44 major sites (Figure 1) including major wetlands, terrestrial habitats, and all five protected areas. Several other sites—Janakpur, Chirmiri, and Jhagrakhand-Manendragarh (Sonhat tehsils of Koriya District); Mainpat, Batauli, Sitapur and their surroundings (Surguja District); Lakhanpur block and Jamgala-Nawaparakhurd forest area (Surajpur District); Dharamjaigarh-Lailunga and Gharghoda (Raigarh District); Neemgaon tank, Kailash Gufa, Kunkuri, and Kasabel tehsils (Jashpur District)—were also studied. Major wetlands covered during the study include Jhumka dam and Gej dam (Koriya District); Barnai dam and Ghunghuta dam (Surguja District); Khamarpakut dam, Dilipsingh-Joodeo dam,and Kurkut (Robo) dam (Raigarh District). The river banks and water of the Hasdeo River, Rihand River, and Banas River in Koriya District; Kello River and Mahanadi Riverin Raigarh District were also surveyed. Several other isolated and random sites were also covered.

Efforts were made to collect as much data as possible by compiling past studies and present field observations. These covered habitat types, namely, Sal forest, wetlands, mixed forest, riverine patches, agricultural lands, grasslands, and coal & bauxite mine areas. The maximum possible area was covered between 1995 and intermittently up to 2019, covering all seasons (winter, summer, and monsoon), with emphasis on mornings (0630–0930 h) and evenings (1600–1800 h) (Vishwakarma et al. 2020a). The methodology used was by travelling through the geographical areas of districts, random walks, visual observations, following Javed & Kaul (2002). The aid of binoculars and cameras was deployed whereever possible. The encountered bird species were documented in daily field diaries. The species encountered were identified using standard literature by Ali & Ripley (1987), Grimmett et al. (1998, 2014), Fergusen & Christie (2001), and Rasmussen & Anderton (2012). Identification of a few difficult species was confirmed by Bombay Natural History Society-ENVIS or with the assistance of experts. Valid scientific names provided in this note are following Praveen et al. (2020).

RESULTS AND DISCUSSION

During our study, a total of 361 avian species belonging to 18 orders, 74 families (Annexure 1) were reported from the Surguja region of Chhattisgarh. The maximum number of bird species were recorded from Koriya (318 species) followed by Raigarh (260 species), Surguja (162 species), Balrampur (260 species), Surajpur (208 species), and Jashpur (254 species).The Neemgaon tank, Kurket (Robo) dam, Khamarpakut dam, Banas River, Rihand River, and Mahanadi River; forests of Janakpur Tehsil, Gare-Pelma, Sonhat, Udaipur tehsil, Hills of Mainpat, Kailash Gufa, Jamgala-Nawaparakhurd were a few hotspots. Observations indicated that northern Chhattisgarh supports a considerable number of terrestrial and water bird species belonging to residential, migratory, and passerby categories.

Of the total diversity, 261 species (72.3%) are residents, 98 species (27.15%) winter migrants, and two species (0.55%) summer migrants. This study has added 117 species belonging to five order and 18 families including 82 (70.0%) resident species comprising of four rare, 61 common, 17 uncommon, and 35 (30%) migrants species comprising of 28 common, seven uncommon species, to the previous lists. Earlier studies by D'Abreu (1931, 1935), Hewetson (1956), Chakraborty (2008), and Chandra & Boaz (2018 a,b,c,d) have reported the presence of 243 species belonging to 14 orders and 56 families including 190 (78.19%) resident species and 53 (21.81%) migrant species.

The comparative status of previous and present studies has been shown in Table 1.

The species belonging to the family Accipitridae was dominant with 26 species (Figure 2) followed by Muscicapidae with 17 species; Anatidae with 16 species; Ardeidae & Scolopacidae with 13 species each; Motacillidae with 12 species; Phasianidae, Strigidae, Picidae, & Alaudidae with 11 species each; Columbidae & Cuculidae with 10 species each; Hirundinidae & Phylloscopidae with eight species each; Rallidae, Charadriidae, Campephagidae, & Cisticolidae with seven species each; and Laridae, Dicruridae, & Sturnidae with six species each.

Of the 361 species reported from Surguja region, 10 species were threatened and 13 were near threatened as per IUCN Red List (IUCN 2021; Annexure I; Rahmani 2012), which included threeCritically Endangered (CR) species—White-rumped Vulture *Gyps bengalensis*, Indian Vulture *G. indicus*, and Red-headed Vulture *Sarcogyps calvus*; two Endangered (EN) species—Egyptian Vulture *Neophron percnopterus* and Black-bellied Tern *Sterna acuticauda*; six Vulnerable (VU) species—River Tern *Sterna aurantia,* Common Pochard *Aythya ferina*, Lesser Adjutant *Leptoptilos javanicus*, Sarus Crane *Antigone antigone*, Indian Spotted Eagle *Clanga hastata*, and Greater Spotted Eagle *Clanga clanga*; and 13 Near Threatened (NT) species—Woolly-necked Stork *Ciconia episcopus*, Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus*, Oriental Darter *Anhinga melanogaster*, Great Thick-knee *Esacus recurvirostris*, River Lapwing *Vanellus duvaucelii*, Eurasian Curlew *Numenius arquata*, Pallid Harrier *Circus macrourus*, Grey-headed Fish Eagle *Icthyophaga ichthyaetus*, Malabar Pied Hornbill *Anthracoceros coronatus*, Red-necked Falcon *Falco chicquera*, Laggar Falcon *F. jugger*, and Alexandrine Parakeet *Psittacula eupatria*.

The White-rumped Vulture *Gyps bengalensis* was found nesting in Janakpur tehsil of Koriya district and Mainpat area of Surguja district only. Indian Vulture *G. indicus* and Egyptian Vulture *Neophron percnopterus* were observed at GGNP, Koriya District, (A.M.K. Bharos, pers. obs. May 2013). The Egyptian Vulture was resident at Gomarda Wildlife Sanctuary cliffs until 1998 but has disappeared now. It was not seenat most of the earlier known habitats in Surguja, Surajpur, and Jashpur districts. The Lesser Adjutant *Leptoptilos javanicus* was documented nesting at Nawaparakhurd Village, Premnagar Tehsil in Surajpur District,which is the first record from Chhattisgarh and central India (Bharos &

Table 1. Comparative status between studies and outcome.

Study agency	No. of orders	No. of families	No. of species	Threatened species	Status
Previous studies	14	56	244	CR 2, EN 1 , VU 1, NT 5	R191 M53
Our study	18	74	361	CR 3, EN 2, VU 6, NT 13	R264 M97
New species reported	5	18	117	CR 1, VU 4, NT 6	R82 M35

CR—Critically Endangered | EN—Endangered | VU—Vulnerable | R—Resident | M—Migrant.

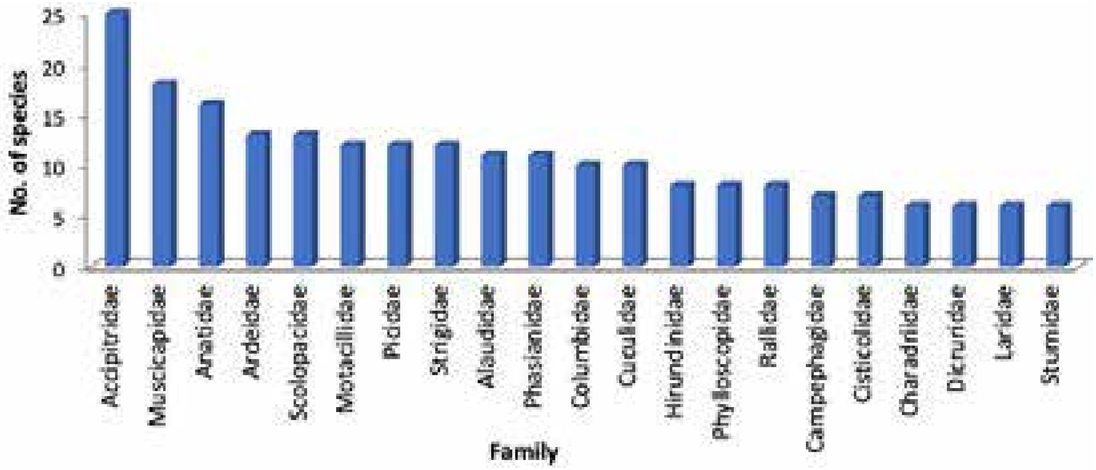

Figure 2. Number of bird species recorded in different families in Surguja region of Chhattisgarh, India.

Diwan 2018; Rahmani et al. 2018).

In previous studies, Sarus Crane was not recorded. In 2015, a pair each of Sarus Crane was found at Lakhanpur Tank and river Rihand (Reher) at location Jamgala in Surajpur District. At Jamgala, their nesting was also reported in 2014 (J. Bhagat pers. comm. 2015). Another potential site of their occurrence is the Bhaiyathan area of river Rihand in Surajpur District (Rahmani et al. 2018). Four nests of Lesser Adjutant were documented in the Surajpur District (Bharos & Diwan 2018), which is the first breeding documentation for the species from central India. There is anunconfirmed record, based on calls, and a sighting of the Endangered Forest Owlet *Heteroglaux blewitti* from Gomarda Wildlife Sanctuary, Raigarh District, situated in the north of its erstwhile habitat (Fuljhar estate) (Rahmani et al. 2018; IUCN 2021).

Since the Surguja region is situated inthe Vindhyachal biographic range, Tyabji (1994) opined that a thorough survey of the whole north-east of MP (now part of Chhattisgarh) may yield some interesting information on the distribution pattern of Himalayan/sub-Himalayan species, whose presence had hitherto been unsuspected in central India. This study recorded ninewinter migrants, which breed in high altitude (1,200–4,000 m) of Himalaya (Baluchistan to Assam),namely, Griffon Vulture *Gyps fulvus* from Manendragarh Tehsil of Koriya District in 1994–95 and Eurasian Hobby *Falco severus* in Mainpat area of Surguja District in 1995. The study also revealed the presence of Grey-headed Canary Flycatcher *Culicicapa ceylonensis*, Common Rose Finch *Carpodacus erythrinus*, Indian Tree Pipit *Anthus trivialis*, Osprey *Pandium haliaetus*, Changeable Hawk-Eagle *Nisaetus* (*Cirrhatus*) *limnaeetus*, Long-legged Buzzard *Buteo rufinus*, and sub-Himalayan species Black-throated Weaver *Ploceus benghalensis*, which breeds in duars/terai up to c. 1,200 m in Uttar Pradesh and Sikkim (Ali & Ripley 1987). These species are regular winter visitors in Surguja and further south in the state. Himalayan Vulture has been found in March 2020 in the Bastar region.

The migratory bird species like the Great Crested Grebe *Podiceps cristatus*, Bar-headed Goose *Anser indicus*, Eurasian Curlew *Numenius arquata*, Bar-tailed Godwit *Limosa lapponica*, Brown-headed Gull *Chroicocephalus brunnicephalus*, Gull-billed Tern *Gelochelidon nilotica*, and Whiskered Tern *Chlidonias hybrid*, have been recorded to use the territory of Surguja and other parts of Chhattisgarh as wintering grounds and also as a stopover during to and fro journeys (Chandra et al. 2015; Bharos 2020; Singh & Vishwakarma 2020). Nesting and congregation of various rare and threatened species such as the presence of 11 species of owls (Strigidae and Tytonidae), five species of vultures (Accipitridae), nesting of Malabar Whistling Thrush *Myophonus horsfieldii*, White-rumped Vulture, Indian Vulture, Egyptian Vulture, Lesser Adjutant, Sarus Crane, and congregation of Grey-headed Lapwing *Vanellus cinereus* prove that Surguja region is a hotspot for birds.

THREATS AND CONSERVATION

The new opencast coal mines had a detrimental impact on the ecology of the region. A study carried out in the core area and 5-km bufferof Singmouza-Jampali (opencast mine) coal block located in Raigarh District, revealed only 492 individuals of 52 bird species belonging to 28 families (Anurag Vishwakarma pers.

obs. 2018). Major disturbances noticed in the core area were sound pollution caused by blasting, air pollution by mining dust, habitat degradation and ground digging, vehicle movements, and anthropogenic pressure, which forced the birds to move away. Mandatory substitute afforestation, in place of habitat destruction, was noticed as casual. Bird species adoption of remnant flowering trees as refuge,which they normally do, was found only occasionally, this aspect was examined in a separate study by Vishwakarma et al. (2020b).

Poaching and trading of birds by the locals is an old tradition of the region, which has been time and again observed. They use traditional and innovative methods to do so, resulting in marked depletion in avifauna belonging to Anatidae, Galliformes, Columbidae families, and any species for that matter. Depletion in the number of peafowls, Yellow-footed Green Pigeon, and Orange-breasted Green Pigeon was noticeable. Big and small mammals, reptiles, and rodents are also not spared.

The whole of Surguja, Surajpur, Balrampur, Korea, Raigarh and adjoining Korba District is a prime coal belt area, with 61,140.6 MT coal reserve mines in operation in three coalfield areas, by South East Coalfield Ltd (2023). Ongoing ambitious projects of Indian Railways, Coal India, Chhattisgarh State Power Generation, and transmission companies, private powergeneration companies, and steel industries to facilitate high productivity, have already had an adverse effect on the rich forests like clear-fellingin sizeable areas, fragmentation, and their flora and fauna. During visits to Jhagrakhand, Ramnagar, and Charcha collieries of Koriya District in 2015, a fewer number of species and population was noticed as compared to the year 1994–95. Infact more species and numbers were seen outside collieries area. A study on birds of Jampali coal mining revealed shifting by birds to other places due to anthropogenic, blasting and rapid forest cutting disturbances (Anurag Vishwakarma pers. obs. 2018). Such a situation is very much in the offing in Raigarh, Surajpur, and Koriya districts. In coming years an environmental impact assessment (EIA) study of the affected areas is suggested which will be of imminent importance to check further deterioration.

CONCLUSION

The present study revealed the presence of 361 bird species in the region, which includes 11 threatened and 13 near threatened species.The dominant bird species encountered belonged to Accipitridae (26 species), followed by Muscicapidae (17 species), and Anatidae (16 species). During this survey, we encountered 117 hitherto unreported bird species, and nine Himalayan and sub-Himalayan species in the Surguja region.The whole of Surguja being a prime coal and bauxite belt area is subjected to large-scale exploitation for commercial purposes. For this purpose, large number of open cast coal mines are being opened. For coal transportation, a network of railways and highways is under progress and a big network of power transmission towers is coming up to provide electricity for these projects. The combined effect of these development activities will certainly have an adverse impact on the environment, as an exemplary study has revealed. Wetlands, though located remotely, are less studied but are subjected to the immense pressure of commercial fishing, siltation, mining, degradation of a catchment area, and amusement activities. EIA study of the region is the need of the hour to redress conservation issues. Awareness programs must be started immediately by the government with the assistance of staff and NGOs to inculcate in the community the sense and responsibilities towards the importance of nature and wildlife and the need to conserve them.

The present study provides a baseline data for future ornithological studies, which need to be intensified in both surveyed and non surveyed potential pockets to determine the updated status.

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Annexure 1. An updated list of birds of Surguja region, Chhattisgarh, India.

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
1	Anseriformes	Anatidae	Lesser Whistling Duck	*Dendrocygna javanica*	LC	R, C	Y	
2			Bar-headed Goose	*Anser indicus*	LC	WM, C	Y	
3			Greylag Goose	*Anser anser*	LC	WM, UC	Y	
4			Ruddy Shelduck	*Tadorna ferruginea*	LC	WM, C	Y	
5			Red-crested Pochard	*Netta rufina*	LC	WM, C	Y	
6			Common Pochard	*Aythya ferina*	VU	WM, C	Y	1, 2, 3, 4
7			Tufted Duck	*Aythya fuligula*	LC	WM, C		New 1, 4
8			Garganey	*Spatula querquedula*	LC	WM, C		New 1, 4
9			Northern Shoveler	*Spatula clypeata*	LC	WM, UC	Y	
10			Gadwall	*Mareca strepera*	LC	WM, C	Y	
11			Eurasian Wigeon	*Mareca penelope*	LC	WM, UC	Y	
12			Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	R, C		New 1, 2, 3, 4
13			Northern Pintail	*Anas acuta*	LC	WM, C	Y	
14			Common Teal	*Anas crecca*	LC	WM, C	Y	
15			Comb Duck	*Sarkidiornis melanotos*	LC	R, C		New 2, 4
16			Cotton Teal	*Nettapus coromandelianus*	LC	R, C	Y	
17	Galliformes	Phasianidae	Indian Peafowl	*Pavo cristatus*	LC	R, C	Y	
18			Common Quail	*Coturnix coturnix*	LC	R, UC	Y	
19			Rain Quail	*Coturnix coromandelica*	LC	R, C	Y	
20			Jungle Bush Quail	*Perdicula asiatica*	LC	R, C	Y	
21			Rock Bush Quail	*Perdicula argoondah*	LC	R, UC		New 1, 4
22			Black Francolin	*Francolinus francolinus*	LC	R, UC	Y	
23			Painted Francolin	*Francolinus pictus*	LC	R, C	Y	
24			Grey Francolin	*Francolinus pondicerianus*	LC	R, C	Y	
25			Red Junglefowl	*Gallus gallus*	LC	R, C	Y	
26			Red Spurfowl	*Galloperdix spadicea*	LC	R, C	Y	
27			Painted Spurfowl	*Galloperdix lunulata*	LC	R, C	Y	
28	Phoenicopteriformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	LC	R, C	Y	
29			Great Crested Grebe	*Podiceps cristatus*	LC	WM, C		New 1,2,4

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
30	Columbiformes	Columbidae	Rock Pigeon	*Columba livia*	LC	R, C	Y	
31			Oriental Turtle Dove	*Streptopelia orientalis*	LC	R, C	Y	
32			Eurasian Collared Dove	*Streptopelia decaocto*	LC	R, C	Y	
33			Red Collared Dove	*Streptopelia tranquebarica*	LC	R, C	Y	
34			Spotted Dove	*Streptopelia chinensis*	LC	R, C	Y	
35			Laughing Dove	*Streptopelia senegalensis*	LC	R, C	Y	
36			Orange-breasted Green Pigeon	*Treron bicinctus*	LC	R, UC		New 1,2,3,4
37			Yellow-legged Green Pigeon	*Treron phoenicopterus*	LC	R, C	Y	
38			Emerald Dove	*Chalcophaps indica*	LC	R, UC	Y	
39			Green Imperial Pigeon	*Ducula aenea*	LC	R, UC	Y	
40	Pterocliformes	Pteroclidae	Chestnut-bellied Sandgrouse	*Pterocles exustus*	LC	R, C		New 2,4
41	Caprimulgiformes	Caprimulgidae	Grey Nightjar	*Caprimulgus indicus*	LC	R, C	Y	
42			Indian Nightjar	*Caprimulgus asiaticus*	LC	R, C	Y	
43			Savanna Nightjar	*Caprimulgus affinis*	LC	R, C		New 4
44			Large-tailed Nightjar	*Caprimulgus macrurus*	LC	R, UC		New 4
45		Apodidae	Crested Treeswift	*Hemiprocne coronata*	LC	R, C	Y	
46			White-rumped Spinetail	*Zoonavena sylvatica*	LC	R, C		New 1,2,3,4
47			White-throated Needletail	*Hirundapus caudacutus*	LC	R, UC		New 4
48			Asian Palm Swift	*Cypsiurus balasiensis*	LC	R, C	Y	
49			Indian House Swift	*Apus affinis*	LC	R, C	Y	
50	Cuculiformes	Cuculidae	Greater Coucal	*Centropus sinensis*	LC	R, C	Y	
51			Sirkeer Malkoha	*Taccocua leschenaultii*	LC	R, UC	Y	
52			Pied Cuckoo	*Clamator jacobinus*	LC	SM, C	Y	
53			Asian Koel	*Eudynamys scolopaceus*	LC	R, C	Y	
54			Plaintive Cuckoo	*Cacomantis merulinus*	LC	R, C	Y	
55			Grey-bellied Cuckoo	*Cacomantis passerinus*	LC	R, C		New
56			Drongo Cuckoo	*Surniculus lugubris*	LC	R, UC		New
57			Common Hawk Cuckoo	*Hierococcyx varius*	LC	R, C	Y	
58			Indian Cuckoo	*Cuculus micropterus*	LC	R, UC	Y	
59			Common Cuckoo	*Cuculus canorus*	LC	R, UC		New

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
60	Gruiformes	Rallidae	Slaty-legged Crake	*Rallina eurizonoides*	LC	R, C	Y	
61			Slaty-breasted Rail	*Lewinia striata*	LC	R, UC	NO	
62			Brown Crake	*Zapornia akool*	LC	R, C		New
63			White-breasted Waterhen	*Amaurornis phoenicurus*	LC	R, C	Y	
64			Grey-headed Swamphen	*Porphyrio poliocephalus*	LC	R, C	Y	New
65			Common Moorhen	*Gallinula chloropus*	LC	R, C	Y	
66			Common Coot	*Fulica atra*	LC	WM, C	Y	
67			Sarus Crane	*Antigone antigone*	**VU**	R, RA		
68		Gruidae	Lesser Adjutant	*Leptoptilos javanicus*	**VU**	R, RA		New 1
69	Ciconiiformes	Ciconiidae	Painted Stork	*Mycteria leucocephala*	**NT**	R, C		New 1, 4
70			Asian Openbill	*Anastomus oscitans*	LC	R, C	Y	New 1, 2, 3, 4
71			Black Stork	*Ciconia nigra*	LC	WM, C		
72			Woolly-necked Stork	*Ciconia episcopus*	**NT**	R, C	Y	New 4
73			Eurasian Bittern	*Botaurus stellaris*	LC	WM, UC		1, 2, 3, 4
74	Pelecaniformes	Ardeidae	Yellow Bittern	*Ixobrychus sinensis*	LC	R, C		New 1
75			Cinnamon Bittern	*Ixobrychus cinnamomeus*	LC	R, C	Y	New2, 4
76			Black Bittern	*Ixobrychus flavicollis*	LC	R, C		
77			Black-crowned Night Heron	*Nycticorax nycticorax*	LC	R, C	Y	New 1, 2, 4
78			Striated Heron	*Butorides striata*	LC	R, UC		
79			Indian Pond Heron	*Ardeola grayii*	LC	R, C	Y	New 1, 2, 3, 4
80			Cattle Egret	*Bubulcus ibis*	LC	R, C	Y	
81			Grey Heron	*Ardea cinerea*	LC	R, C	Y	
82			Purple Heron	*Ardea purpurea*	LC	R, C	Y	
83			Great Egret	*Ardea alba*	LC	R, C		
84			Intermediate Egret	*Ardea intermedia*	LC	R, C	Y	New 1, 2, 3, 4
85			Little Egret	*Egretta garzetta*	LC	R, C	Y	
86			Black-headed Ibis	*Threskiornis melanocephalus*	NT	R, C	Y	
87		Threskiornithidae	Eurasian Spoonbill	*Platalea leucorodia*	LC	R, UC		1, 2, 3, 4
88			Red-naped Ibis	*Pseudibis papillosa*	LC	R, C	Y	New 4
89			Glossy Ibis	*Plegadis falcinellus*	LC	R, UC	Y	
90			Little Cormorant	*Microcarbo niger*	LC	R, C	Y	

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
91	Pelecaniformes	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	LC	R, C		
92			Indian Cormorant	*Phalacrocorax fuscicollis*	LC	R, C	Y	New 1, 2, 3, 4
93			Oriental Darter	*Anhinga melanogaster*	NT	R, C	Y	
94		Anhingidae	Eurasian Thick-knee	*Burhinus oedicnemus*	LC	R, C		2, 4
95	Charadriiformes	Burhinidae	Great Thick-knee	*Esacus recurvirostris*	NT	R, RA		New
96			Black-winged Stilt	*Himantopus himantopus*	LC	R, C	Y	New 4
97		Recurvirostridae	Little Ringed Plover	*Charadrius dubius*	LC	R, C	Y	
98		Charadriidae	Kentish Plover	*Charadrius alexandrinus*	LC	WM, C		
99			River Lapwing	*Vanellus duvaucelii*	NT	R, UC		New 1, 2, 3, 4
100			Yellow-wattled Lapwing	*Vanellus malarbaricus*	LC	R, C	Y	New 2, 4
101			Grey-headed Lapwing	*Vanellus cinereus*	LC	M, UC		
102			Red-wattled Lapwing	*Vanellus indicus*	LC	R, C	Y	New 1, 4
103			Greater Painted-snipe	*Rostratula benghalensis*	LC	R, C	Y	
104		Rostratulidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	LC	R, C	Y	
105		Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	LC	R, C	Y	
106			Eurasian Curlew	*Numenius arquata*	NT	WM, UC	Y	
107		Scolopacidae	Temminck's Stint	*Calidris temminckii*	LC	WM, C		4
108			Little Stint	*Calidris minuta*	LC	WM, C		New 1, 2, 4
109			Pintail Snipe	*Gallinago stenura*	LC	R, C		New 1, 2, 3, 4
110			Common Snipe	*Gallinago gallinago*	LC	R, UC	Y	New 2, 4
111			Jack Snipe	*Lymnocryptes minimus*	LC	R, RA		
112			Common Sandpiper	*Actitis hypoleucos*	LC	WM, C	Y	New
113			Green Sandpiper	*Tringa ochropus*	LC	WM, C	Y	
114			Spotted Redshank	*Tringa erythropus*	LC	WM, C	Y	
115			Common Greenshank	*Tringa nebularia*	LC	WM, C	Y	
116			Common Redshank	*Tringa totanus*	LC	WM, C	Y	
117			Wood Sandpiper	*Tringa glareola*	LC	WM, C	Y	
118			Marsh Sandpiper	*Tringa stagnatilis*	LC	WM, UC		
119			Small Buttonquail	*Turnix sylvaticus*	LC	R, UC		New 1, 4

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
120	Charadriiformes	Turnicidae	Yellow-legged Buttonquail	*Turnix tanki*	LC	R, UC	Y	New 2, 4
121			Barred Buttonquail	*Turnix suscitator*	LC	R, C	Y	
122			Indian Courser	*Cursorius coromandelicus*	LC	R, C		
123		Glareolidae	Little Pratincole	*Glareola lactea*	LC	R, C	Y	New 1, 4
124			Brown-headed Gull	*Chroicocephalus brunnicephalus*	LC	WM, C		
125		Laridae	Black-headed Gull	*Chroicocephalus ridibundus*	LC	WM, C		New1, 2, 4
126			Gull-billed Tern	*Gelochelidon nilotica*	LC	WM, UC		New 1, 2, 4
127			Whiskered Tern	*Chlidonias hybrida*	LC	WM, UC		New 4
128			River Tern	*Sterna aurantia*	VU	WM, C	Y	New 4
129			Black-bellied Tern	*Sterna acuticauda*	EN	WM, UC	Y	1, 2, 3, 4
130			Osprey	*Pandion haliaetus*	LC	WM, C	Y	1, 4
131	Accipitriformes	Pandionidae	Black-winged Kite	*Elanus caeruleus*	LC	R, C	Y	
132		Accipitridae	Oriental Honey Buzzard	*Pernis ptilorhynchus*	LC	R, C	Y	
133			Egyptian Vulture	*Neophron percnopterus*	EN	R, RA	Y	
134			Crested Serpent Eagle	*Spilornis cheela*	LC	R, C	Y	1, 3
135			Short-toed Snake Eagle	*Circaetus gallicus*	LC	R, C	Y	
136			Red-headed Vulture	*Sarcogyps calvus*	CE	R, RA		
137			White-rumped Vulture	*Gyps bengalensis*	CE	R, UC	Y	New 1
138			Griffon Vulture	*Gyps fulvus*	LC	WM, RA		1, 2, 3, 4
139			Indian Vulture	*Gyps indicus*	CE	R, RA	Y	New 1
140			Changeable Hawk Eagle	*Nisaetus cirrhatus*	LC	R, UC	Y	1, 2, 3, 4
141			Black Eagle	*Ictinaetus malaiensis*	LC	R, C		
142			Indian Spotted Eagle	*Clanga hastata*	VU	R, C		New 1
143			Greater Spotted Eagle	*Clanga clanga*	VU	R, UC		New 4
144			Bonelli's Eagle	*Aquila fasciata*	LC	R, C	Y	New 4
145			Booted Eagle	*Hieraaetus pennatus*	LC	WM, C		
146			Western Marsh Harrier	*Circus aeruginosus*	LC	WM, C		New 1, 2, 3, 4
147			Pallid Harrier	*Circus macrourus*	NT	WM, UC		New 1, 2, 3, 4
148			Montagu's Harrier	*Circus pygargus*	LC	WM, C		New 1, 4
149			Crested Goshawk	*Accipiter trivirgatus*	LC	R, UC	Y	New 2, 4
150			Shikra	*Accipiter badius*	LC	R, C	Y	

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
151	Accipitriformes	Accipitridae	Eurasian Sparrowhawk	*Accipiter nisus*	LC	WM, C	Y	
152			Grey-headed Fish Eagle	*Icthyophaga ichthyaetus*	NT	R, UC	Y	
153			Brahminy Kite	*Haliastur indus*	LC	R, UC	Y	4
154			Black Kite	*Milvus migrans*	LC	R, C		
155			White-eyed Buzzard	*Butastur teesa*	LC	R, C	Y	New 1, 2, 3, 4
156			Common Barn Owl	*Tyto alba*	LC	R, C	Y	
157	Strigiformes	Tytonidae	Brown Hawk Owl	*Ninox scutulata*	LC	R, UC	Y	
158		Strigidae	Jungle Owlet	*Glaucidium radiatum*	LC	R, C	Y	
159			Spotted Owlet	*Athene brama*	LC	R, C	Y	
160			Eurasian Scops Owl	*Otus scops*	LC	R, UC	Y	
161			Collared Scops Owl	*Otus bakkamoena*	LC	R, C	Y	
162			Mottled Wood Owl	*Strix ocellata*	LC	R, C		
163			Brown Wood Owl	*Strix leptogrammica*	LC	R, C		New 1, 3, 4
164			Eurasian Eagle Owl	*Bubo bubo*	LC	R, C	Y	New 4
165			Indian Eagle Owl	*Bubo bengalensis*	LC	R, UC		
166			Dusky Eagle Owl	*Bubo coromandus*	LC	R, RA	Y	New 1, 2, 3, 4
167			Oriental Scops-Owl	*Otus sunia*	LC	R, UC		
168			Brown Fish Owl	*Ketupa zeylonensis*	LC	R, C	Y	New 4
169			Malabar Pied Hornbill	*Anthracoceros coronatus*	NT	R, UC	Y	
170	Bucerotiformes	Bucerotidae	Indian Grey Hornbill	*Ocyceros birostris*	LC	R, C	Y	2,4
171			Common Hoopoe	*Upupa epops*	LC	R, C	Y	
172		Upupidae	Greater Flameback	*Chrysocolaptes guttacristatus*	LC	R, C		
173	Piciformes	Picidae	Northern Wryneck	*Jynx torquilla*	LC	WM, C	Y	New 1, 2, 3, 4
174			Lesser Golden-backed Woodpecker	*Dinopium benghalense*	LC	R, C	Y	
175			Rufous Woodpecker	*Micropternus brachyurus*	LC	R, C	Y	
176			Streak-throated Woodpecker	*Picus xanthopygaeus*	LC	R, UC	Y	
177			Scaly-bellied Woodpecker	*Picus squamatus*	LC	R, UC		
178			Greater Golden-backed Woodpecker	*Chrysocolaptes lucidus*	LC	R, C		New 4
179			White-naped Woodpecker	*Chrysocolaptes festivus*	LC	R, C	Y	New 1, 2, 3, 4
180			Brown-capped Pygmy Woodpecker	*Dendrocopos moluccensis*	LC	R, C	Y	

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181	Piciformes	Picidae	Grey-capped Pygmy Woodpecker	*Dendrocopos canicapillus*	LC	R, C	Y	
182			Fulvous-breasted Woodpecker	*Dendrocopos macei*	LC	R, C	Y	
183			Yellow-crowned Woodpecker	*Dendrocopos mahrattensis*	LC	R, C	Y	
184			Brown-headed Barbet	*Psilopogon zeylanicus*	LC	R, C	Y	
185		Ramphastidae	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	R, C	Y	
186			Green Bee-eater	*Merops orientalis*	LC	R, C	Y	
187	Coraciiformes	Meropidae	Chestnut-headed Bee-eater	*Merops leschenaulti*	LC	R, C	Y	
188			Blue-tailed Bee-eater	*Merops philippinus*	LC	R, C	Y	
189			Indian Roller	*Coracias benghalensis*	LC	R, C	Y	
190		Coraciidae	Common Kingfisher	*Alcedo atthis*	LC	R, C	Y	
191		Alcedinidae	Pied Kingfisher	*Ceryle rudis*	LC	R, C	Y	
192			Stork-billed Kingfisher	*Pelargopsis capensis*	LC	R, UC	Y	
193			White-throated Kingfisher	*Halcyon smyrnensis*	LC	R, C	Y	
194			Common Kestrel	*Falco tinnunculus*	LC	WM, C	Y	
195	Falconiformes	Falconidae	Red-necked Falcon	*Falco chicquera*	NT	R, C	Y	
196			Oriental Hobby	*Falco severus*	LC	WM, RA		1, 2, 4
197			Laggar Falcon	*Falco jugger*	NT	WM, UC		New 1
198			Peregrine Falcon	*Falco peregrinus*	LC	R, C		New 1, 4
199			Plum-headed Parakeet	*Psittacula cyanocephala*	LC	R, C	Y	New 1, 3, 4
200	Psittaciformes	Psittaculidae	Alexandrine Parakeet	*Psittacula eupatria*	NT	R, C	Y	
201			Rose-ringed Parakeet	*Psittacula krameri*	LC	R, C	Y	1, 2, 3, 4
202			Indian Pitta	*Pitta brachyura*	LC	SM, C	Y	
203	Passeriformes	Pittidae	White-bellied Minivet	*Pericrocotus erythropygius*	LC	R, UC		
204		Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	LC	R, C	Y	New 1, 3
205			Scarlet Minivet	*Pericrocotus flammeus*	LC	R, C	Y	
206			Rosy Minivet	*Pericrocotus roseus*	LC	R, UC	Y	
207			Large Cuckooshrike	*Coracina javensis*	LC	R, C	Y	
208			Black-winged Cuckooshrike	*Lalage melaschistos*	LC	R, UC	Y	
209			Black-headed Cuckooshrike	*Lalage melanoptera*	LC	R, C	Y	
210			Black-hooded Oriole	*Oriolus xanthornus*	LC	R, C	Y	

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211	Passeriformes	Oriolidae	Eurasian Golden Oriole	*Oriolus oriolus*	LC	R, C	Y	
212			Indian Golden Oriole	*Oriolus kundoo*	LC	R, C		
213			Black-naped Oriole	*Oriolus chinensis*	LC	WM, UC		New 1, 2, 3, 4
214			Ashy Woodswallow	*Artamus fuscus*	LC	R, C		New 4
215		Artamidae	Bar-winged Flycatcher-shrike	*Hemipus picatus*	LC	R, UC		New 1, 4
216		Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*	LC	R, C	Y	New 4
217			Common Iora	*Aegithina tiphia*	LC	R, C	Y	
218		Aegithinidae	Marshall's Iora	*Aegithina nigrolutea*	LC	R, UC		
219			Black Drongo	*Dicrurus macrocercus*	LC	R, C	Y	New 1
220		Dicruridae	Ashy Drongo	*Dicrurus leucophaeus*	LC	R, C		
221			White-bellied Drongo	*Dicrurus caerulescens*	LC	R, C	Y	New 1, 2, 4
222			Bronzed Drongo	*Dicrurus aeneus*	LC	R, UC	Y	
223			Hair-crested Drongo	*Dicrurus hottentottus*	LC	R, C	Y	
224			Greater Racket-tailed Drongo	*Dicrurus paradiseus*	LC	R, C	Y	
225			White-browed Fantail	*Rhipidura aureola*	LC	R, C	Y	
226		Rhipiduridae	Spot-breasted Fantail (White-spotted Fantail)	*Rhipidura albogularis*	LC	R, UC		
227			White-throated Fantail	*Rhipidura albicollis*	LC	R, UC	Y	New 4
228			Brown Shrike	*Lanius cristatus*	LC	WM, C	Y	
229		Laniidae	Isabelline Shrike	*Lanius isabellinus*	LC	WM		
230			Bay-backed Shrike	*Lanius vittatus*	LC	R, C	Y	New 4
231			Long-tailed Shrike	*Lanius schach*	LC	R, C	Y	
232			Great Grey Shrike	*Lanius excubitor*	LC	R, C		
233			Rufous Treepie	*Dendrocitta vagabunda*	LC	R, C	Y	New 1, 4
234		Corvidae	House Crow	*Corvus splendens*	LC	R, C	Y	
235			Large-billed Crow	*Corvus macrorhynchos*	LC	R, C	Y	
236			Black-naped Monarch	*Hypothymis azurea*	LC	R, C	Y	
237		Monarchidae	Indian Paradise-flycatcher	*Terpsiphone paradisi*	LC	R, C	Y	
238			Thick-billed Flowerpecker	*Dicaeum agile*	LC	R, C	Y	
239		Dicaeidae	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	LC	R, C	Y	
240			Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	R, C	Y	

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241	Passeriformes	Nectariniidae	Crimson-backed Sunbird	*Leptocoma minima*	LC	R, UC		
242			Purple Sunbird	*Cinnyris asiaticus*	LC	R, C		New 4
243			Golden-fronted Leafbird	*Chloropsis aurifrons*	LC	R, C	Y	New 1, 2, 3, 4
244		Irenidae	Jerdon's Leafbird	*Chloropsis jerdoni*	LC	R, C	Y	
245			Baya Weaver	*Ploceus philippinus*	LC	R, C	Y	
246		Ploceidae	Red Munia	*Amandava amandava*	LC	R, C	Y	
247		Estrildidae	Indian Silverbill	*Euodice malabarica*	LC	R, C	Y	
248			White-rumped Munia	*Lonchura striata*	LC	R, C	Y	
249			Scaly-breasted Munia	*Lonchura punctulata*	LC	R, C	Y	
250			Black-headed Munia	*Lonchura malacca*	LC	R, C	Y	
251			House Sparrow	*Passer domesticus*	LC	R, C		
252		Passeridae	Yellow-throated Sparrow	*Gymnoris xanthocollis*	LC	R, C	Y	New 1, 2, 3, 4
253			Forest Wagtail	*Dendronanthus indicus*	LC	WM, UC	Y	
254		Motacillidae	Tree Pipit	*Anthus trivialis*	LC	WM, C	Y	
255			Olive-backed Pipit	*Anthus hodgsoni*	LC	WM, C	Y	
256			Paddyfield Pipit	*Anthus rufulus*	LC	R, C	Y	
257			Blyth's Pipit	*Anthus godlewskii*	LC	WM, UC		
258			Tawny Pipit	*Anthus campestris*	LC	WM, C		New 4
259			Western Yellow Wagtail	*Motacilla flava*	LC	WM, C	Y	New 1, 4
260			Grey Wagtail	*Motacilla cinerea*	LC	WM, C	Y	
261			Citrine Wagtail	*Motacilla citreola*	LC	WM, C		
262			Eastern Yellow Wagtail	*Motacilla tschutschensis*	LC	WM, C		New 1, 4
263			White-browed Wagtail	*Motacilla maderaspatensis*	LC	R, C	Y	New 1, 3, 4
264			White Wagtail	*Motacilla alba*	LC	WM, C	Y	
265			Common Rosefinch	*Erythrina erythrina*	LC	WM, C	Y	
266		Fringillidae	Crested Bunting	*Melophus lathami*	LC	R, C	Y	
267		Emberizidae	Red-headed Bunting	*Granativora bruniceps*	LC	WM, C		
268			Black-headed Bunting	*Granativora melanocephala*	LC	WM, C		New 1, 4
269			Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	LC	WM, C	Y	New 1, 4
270		Stenostiridae	Yellow-browed Tit	*Sylviparus modestus*	LC	R, UC		

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271	Passeriformes	Paridae	Indian Yellow Tit -	*Machlolophus aplonotus*	LC	R, C	Y	New 1, 2, 4
272			Cinereous Tit	*Parus cinereus*	LC	R, C	Y	
273			Black-lored Tit	*Machlolophus xanthogenys*	LC	R, UC		
274			Yellow-cheeked Tit	*Machlolophus spilonotus*	LC	R, C		New 4
275			Rufous-tailed Lark	*Ammomanes phoenicura*	LC	R, C	Y	New 1, 4
276		Alaudidae	Ashy-crowned Sparrow Lark	*Eremopterix griseus*	LC	R, C	Y	
277			Singing Bushlark	*Mirafra cantillans*	LC	R, C	Y	
278			Bengal Bushlark	*Mirafra assamica*	LC	R, C	Y	
279			Indian Bushlark	*Mirafra erythroptera*	LC	R, C	Y	
280			Jerdon's Bushlark	*Mirafra affinis*	LC	R, UC		
281			Greater Short-toed Lark	*Calandrella brachydactyla*	LC	WM, C	Y	New 4
282			Sykes's Short-toed Lark (Eastern Short-toed Lark)	*Calandrella dukhunensis*	LC	WM, C		
283			Eurasian Skylark	*Alauda arvensis*	LC	R, C		New 1, 2, 3, 4
284			Oriental Skylark	*Alauda gulgula*	LC	R, C	Y	New 1, 2
285			Sykes's Lark	*Galerida deva*	LC	R, UC		
286			Zitting Cisticola	*Cisticola juncidis*	LC	R, C	Y	New 2, 4
287		Cisticolidae	Rufous-fronted Prinia	*Prinia buchanani*	LC	R, C	Y	
288			Grey-breasted Prinia	*Prinia hodgsonii*	LC	R, C	Y	
289			Jungle Prinia	*Prinia sylvatica*	LC	R, C	Y	
290			Ashy Prinia	*Prinia socialis*	LC	R, C	Y	
291			Plain Prinia	*Prinia inornata*	LC	R, C	Y	
292			Common Tailorbird	*Orthotomus sutorius*	LC	R, C	Y	
293			Booted Warbler	*Iduna caligata*	LC	WM, C	Y	
294		Acrocephalidae	Sykes's Warbler	*Iduna rama*	LC	WM, UC		
295			Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	WM, C	Y	New 4
296			Paddyfield Warbler	*Acrocephalus agricola*	LC	WM, C		
297			Clamorous Reed Warbler	*Acrocephalus stentoreus*	LC	WM, C		New 1, 2, 3, 4
298			Northern House Martin	*Delichon urbicum*	LC	WM, UC	Y	New 1, 2, 4

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299	Passeriformes	Hirundinidae	Streak-throated Swallow	*Petrochelidon fluvicola*	LC	WM, C	Y	
300			Red-rumped Swallow	*Cecropis daurica*	LC	WM, C	Y	
301			Wire-tailed Swallow	*Hirundo smithii*	LC	R, C	Y	
302			Barn Swallow	*Hirundo rustica*	LC	WM, C	Y	
303			Dusky Crag Martin	*Ptyonoprogne concolor*	LC	R, UC	Y	
304			Plain Martin	*Riparia paludicola*	LC	R, C		
305			Sand Martin	*Riparia riparia*	LC	R, UC		New 1, 3, 4
306			Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	R, C	Y	New 1, 3, 4
307		Pycnonotidae	White-eared Bulbul	*Pycnonotus leucotis*	LC	R, RA		
308			Red-vented Bulbul	*Pycnonotus cafer*	LC	R, C	Y	New 1, 3
309			Black-headed Bulbul	*Brachypodius atriceps*	LC	R, C		
310			Hume's Warbler	*Phylloscopus humei*	LC	WM, C		New 4
311		Phylloscopidae	Common Chiffchaff	*Phylloscopus collybita*	LC	WM, C	Y	New 1, 2, 3, 4
312			Plain Leaf Warbler	*Phylloscopus neglectus*	LC	WM, UC		
313			Sulphur-bellied Warbler	*Phylloscopus griseolus*	LC	WM, C	Y	New 1, 4
314			Tickell's Leaf Warbler	*Phylloscopus affinis*	LC	WM, UC		
315			Western Crowned Warbler	*Phylloscopus occipitalis*	LC	WM, C		New 4
316			Green Warbler	*Phylloscopus nitidus*	LC	WM, C		New 1, 4
317			Greenish Warbler	*Phylloscopus trochiloides*	LC	WM, C		New 1, 4
318			Eastern Orphean Warbler	*Curruca crassirostris*	LC	WM, UC	Y	New 1, 4
319		Sylviidae	Lesser Whitethroat	*Curruca curruca*	LC	WM, C	Y	
320			Common Whitethroat	*Curruca communis*	LC	WM, UC		
321			Yellow-eyed Babbler	*Chrysomma sinense*	LC	R, C	Y	New 1, 2, 3, 4
322			Oriental White-eye	*Zosterops palpebrosus*	LC	R, C	Y	
323		Zosteropidae	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	LC	R, C	Y	
324		Timaliidae	Tawny-bellied Babbler	*Dumetia hyperythra*	LC	R, C		
325			Rufous-capped Babbler	*Cyanoderma ruficeps*	LC	R, UC	Y	New 4
326			Yellow-throated Fulvetta	*Schoeniparus cinereus*	LC	R, UC		
327		Pellorneidae	Puff-throated Babbler	*Pellorneum ruficeps*	LC	R, C		New 4
328			Brown-cheeked Fulvetta	*Alcippe poioicephala*	LC	R, C		New 4
329			Large Grey Babbler	*Argya malcolmi*	LC	R, C	Y	New 4

	Order	Family	Species name	Scientific name	IUCN Red List status	Residential status	Previous studies	New & source
330	Passeriformes	Leiothrichidae	Common Babbler	*Argya caudata*	LC	R, C	Y	
331			Jungle Babbler	*Turdoides striata*	LC	R, C	Y	
332			Yellow-billed Babbler	*Turdoides affinis*	LC	R, UC		
333			Chestnut-bellied Nuthatch	*Sitta castanea*	LC	R, C	Y	New 4
334		Sittidae	Velvet-fronted Nuthatch	*Sitta frontalis*	LC	R, C	Y	
335			Indian Spotted Creeper	*Salpornis spilonota*	LC	R, UC		
336			Rosy Starling	*Pastor roseus*	LC	WM, C		New 4
337		Sturnidae	Asian Pied Starling	*Gracupica contra*	LC	R, C	Y	New 1, 3, 4
338			Brahminy Starling	*Sturnia pagodarum*	LC	R, C	Y	
339			Chestnut-tailed Starling	*Sturnia malabarica*	LC	R, C		
340			Common Myna	*Acridotheres tristis*	LC	R, C	Y	New 1, 2, 3, 4
341			Jungle Myna	*Acridotheres fuscus*	LC	R, UC	Y	
342			Indian Robin	*Saxicoloides fulicatus*	LC	R, C	Y	
343		Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	LC	R, C	Y	
344			White-rumped Shama	*Kittacincla malabarica*	LC	R, C	Y	
345			Asian Brown Flycatcher	*Muscicapa dauurica*	LC	R, C	Y	
346			Tickell's Blue Flycatcher	*Cyornis tickelliae*	LC	R, C	Y	
347			Blue-throated Blue Flycatcher	*Cyornis rubeculoides*	LC	WM, UC	Y	
348			Verditer Flycatcher	*Eumyias thalassinus*	LC	WM, C	Y	
349			Bluethroat	*Luscinia svecica*	LC	WM, C	Y	
350			Red-breasted Flycatcher	*Ficedula parva*	LC	WM, C	Y	
351			Taiga Flycatcher	*Ficedula albicilla*	LC	WM, C		
352			Ultramarine Flycatcher	*Ficedula superciliaris*	LC	WM, C	Y	New 2, 4
353			Black Redstart	*Phoenicurus ochruros*	LC	WM, C	Y	
354			Blue-capped Rock Thrush	*Monticola cinclorhyncha*	LC	WM, UC		
355			Blue Rock Thrush	*Monticola solitarius*	LC	WM, C		New 4
356			Malabar Whistling-Thrush	*Myophonus horsfieldii*	LC	R, C		New 1, 4
357			Siberian Stonechat	*Saxicola maurus*	LC	WM, C	Y	New 1, 2, 3, 4
358			Pied Bushchat	*Saxicola caprata*	LC	R, C	Y	
359			Brown Rock Chat	*Oenanthe fusca*	LC	R, C		
360			Orange-headed Thrush	*Geokichla citrina*	LC	R, C	Y	New 1, 2, 4
361		Turdidae	Tickell's Thrush	*Turdus unicolor*	LC	R, C		

Source: 1—A M K Bharos | 2—Anurag Vishwakarma | 3—AkhileshBharos | 4—Ravi Naidu | Y—Chandra & Boaz 2018 | New—New species recorded. **IUCN Red List status:** CR—Critically Endangered | EN—Endangered | VU—Vulberable | NT—Near Threatened | LC—Least Concern. **Notations:** C—Common | M—Migrant | R—Resident | RA—Rare | SM—Summer Migrant | UC—Uncommon | WM—Winter Migrant.

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COMMUNICATION

Seasonal variation and habitat role in distribution and activity patterns of Red-wattled Lapwing *Vanellus indicus* (Boddaert, 1783) (Aves: Charadriiformes: Charadriidae) in Udaipur, Rajasthan, India

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Abstract: Red-wattled Lapwings *Vanellus indicus* are resident waders in Asia. They usually inhabit areas close to water and are mainly insectivorous. Their principal habitats are grasslands, wetlands, arable lands, gardens and open forests. These highly active and vocal birds are known for their wide range of distraction displays. A field investigation of distribution across different seasons and diverse habitats in Udaipur, Rajasthan was conducted from 2019 to 2021. Populations of lapwings varied significantly among locations, with the largest documented at Fateh Sagar Lake and the lowest at Rang Sagar Lake. Both habitat types and seasons (summer, monsoon and winter) had significant effects on lapwing distribution. Wetlands were the most preferred habitat at ten major study locations, and the monsoon was found to be the most favored season. Bird activity patterns did not exhibit significant variation with seasons, with locomotion, vigilance, feeding and maintenance being the most performed activities.

Keywords: Behavioral activities, habitat preference, lapwings, seasonal effect, vigilance.

Abbreviations: MLSU—Mohanlal Sukhadia University | RCA—Rajasthan College of Agriculture

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Author contributions: SG carried out research work on Red-wattled lapwings under the supervision of Prof. Kanan Saxena. All the photographs and data were collected by him. He performed statistical analyses of data and wrote the manuscript. KS laid out the concept and framework of the research work. The interpretation of results was carried out by her. The manuscript was written under her guidance.

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INTRODUCTION

Red-wattled Lapwings *Vanellus indicus* are resident waders that usually inhabit areas close to water. They are widely distributed throughout Asia, having been reported from India, Iran, Iraq, Kuwait, Oman, Syrian Arab Republic, Turkey, United Arab Emirates, Bangladesh, Bhutan, Cambodia, China, Indonesia, Israel, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Pakistan, Singapore, Sri Lanka, Thailand, and Vietnam (Ali & Ripley 2001; Wiersma & Kirwan 2020; BirdLife International 2023). This species is found in lowlands up to 1,800 m in Sri Lanka, and to at least 2,300 m in the Himalaya. The principal habitats of lapwings are grasslands, wetlands, arable lands, gardens, and open forests (Wiersma & Kirwan 2019). The global population is estimated to be about 50,000 to 60,000 individuals (BirdLife International 2023). The IUCN Red List of Threatened Species classifies Red-wattled Lapwing as 'Least Concern', and it is listed under Schedule IV of the Indian Wildlife Protection Act, 1972.

The literature on the population structure and distribution of Red-wattled Lapwing is limited, and a proper assessment of populations is lacking, probably due to a perceived absence of immediate threats to the species. However, some reports do indicate threats to lapwing populations and habitats. Karakas (2016) recorded 20–30 breeding pairs in Turkey, and reported that the construction of dams posed a threat to the habitats of this species causing population decline and moderate range expansion in search of suitable habitats. Gupta & Kaushik (2011) highlighted habitat destruction and threats to lapwings in Kurukshetra, Haryana.

Red-wattled Lapwings are highly active and vocal birds that are known for their wide range of distraction displays (Kalsi & Khera 1987). These birds are mainly insectivorous but also are known to feed on food grains (Babi 1987), molluscs (Madhava & Botejue 2011) and fishes (Greeshma & Jayson 2019). Studies on the seasonal variations as well as variations in the daily activity patterns with breeding and non-breeding periods have not been reported earlier.

Udaipur city offers unique habitat diversity such as mountain ranges, elevated plateaus, green plains, forests, rivers, and wetlands which explains the choice of this city as the field for study. The presence of ample natural resources such as food and water make the city a perfect haven for bird species such as Red-wattled Lapwings. Thus, the study was conducted to provide baseline information regarding the distribution pattern, habitat preference, and activity patterns of Red-wattled Lapwing at 10 major locations covering diverse habitats of Udaipur city.

MATERIALS AND METHODS

Study area

The field survey was carried out in different areas of Udaipur City (24.585° N and 73.712° E), southern Rajasthan, India between 01 September 2019 to 30 September 2021. The study was conducted during the three main seasons viz. summer (March to June), monsoon (July to September), and winter (October to February). Diverse habitats of Red-wattled Lapwings, such as wetlands, grasslands, open fields, river banks, islands, and gardens were selected for the assessment. The sampling sites were randomly chosen and their GPS (global positioning system) coordinates were determined using Garmin eTrex 20x (Appendix 1, Image 1a) for documenting the distribution pattern of Red-wattled Lapwings. The Red-wattled Lapwings were recorded in wetlands (Lake Fateh Sagar, Lake Pichola, Rang Sagar Lake, Goverdhan Sagar Lake, and Ayad River), crop-fields (farms near Fateh Sagar Lake, Ayad River, and agricultural lands in Rajasthan College of Agriculture (RCA) and Mohanlal Sukhadia University (MLSU) campuses), grasslands (inside MLSU, areas around Fateh Sagar Lake, Goverdhan Sagar Lake, Ayad River, and Sajjangarh Biological Park), urban parks (Sukhadia Memorial Park and Gulab Bagh), protected areas (Sajjangarh Biological Park and Gulab Bagh), institutional green spaces (MLSU and RCA campuses) and constructed buildings, roads, and footpaths (areas around Fateh Sagar Lake, Pichola Lake, Rang Sagar Lake, Goverdhan Sagar Lake, MLSU, and Ayad River) as shown in Image 1b.

Population monitoring

The population survey was carried out by adopting the point count method (Bibby et al. 2000). A total of 288 vantage points (maintained 200 m between two sites) spanning a total area of 37.5 km^2. We spent 5 min at each site and then started documentation of the lapwings without disturbing them. Birds were recorded using binoculars (Nikon Aculon A211 8 x 42) as well as auditory detections (using RecForge II app on a smartphone) within a range of 30 m at each site. Flying birds were not recorded. To analyze the correlation between the influence of season and habitat preference, the number of birds recorded during the first week of the month were selected for each season, viz.: January for

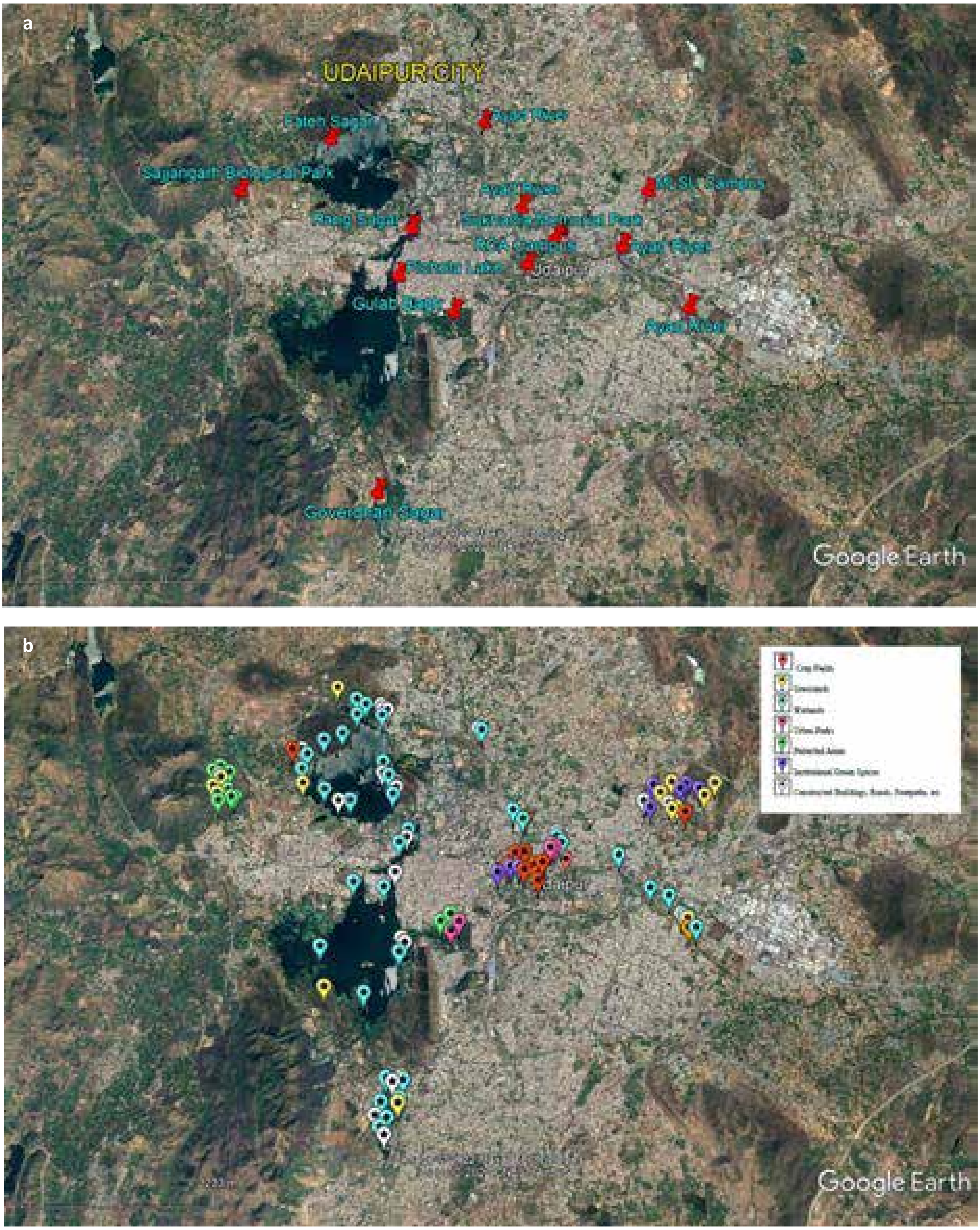

Image 1. a—Satellite map of selected sampling sites in Udaipur city for population survey of Red-wattled Lapwing | b—Satellite map showing diverse habitat areas of Red-wattled Lapwings at the study sites in Udaipur city.

winter, June for summer, and September for monsoon (Chaudhury & Koli 2018).

Activity pattern sampling

Focal sampling and scan sampling techniques (Altmann 1974) were employed to observe the activity patterns of lapwings daily between 0700–1000 h, 1200–1300 h, and 1600–1800 h during different seasons. About 6–8 pairs of birds were randomly selected from diverse habitats. The behaviour was recorded and observed using binoculars at a distance of 15 m to avoid disturbance. Each bird was observed at 5 min time intervals.

The activity patterns of selected birds were recorded for 480 hours during the entire study time. The following activity patterns of Red-wattled Lapwings were observed during the investigation: (i) locomotion, (ii) maintenance, (iii) feeding, (iv) vigilance, (v) vocalizations, (vi) displays, (vii) inactivity, (viii) social interaction, and (ix) miscellaneous activities. Since the birds were not tagged, there was a possibility of recording the activity of birds more than once. However, the probability of deviation in data due to the error gets reduced because the same bird was not recorded more than once during the time of scanning. To ensure that the same bird was not observed more than once during the scanning time, observations were made only of birds that were present throughout the observation time. The activity of a bird that flew away or towards the selected site during a particular observation time was not recorded. Moreover, each bird was observed only for 5 min during every observation cycle and and if birds are presumed to alter their activities with specific factors such as breeding or non-breeding seasons and time, then according to Maruyama et al. 2010, the spotting of same individual more than once doesn't imply strong pseudo-replication.

Statistical analyses

The statistical analyses were carried out using GraphPad Prism and Microsoft Excel software. Two-way analysis of variance (ANOVA) was used to test the significance of the population status of Red-wattled Lapwings in different months (Factor 1) at various sampling sites (Factor 2). Similarly, the numbers of lapwings in diverse habitats (Factor 1) during different seasons (Factor 2) were also tested using the two-way ANOVA method. Mann-Whitney U test and two-way ANOVA were used to study the activities of the birds across different months. A comparative analysis of activities between breeding and the non-breeding season was also performed by carrying out Mann-Whitney U test and multiple-t tests. Further, the activities at various periods during breeding and non-breeding season were also analyzed by two-way ANOVA. Data were computed at a probability level of 5% and were used as the minimal criteria of significance.

Table 1. Population status of *Vanellus indicus* during study periods 2019–2020 and 2020–2021 from all study sites of Udaipur City.

	Sites	2019–2020											2020–2021										
		Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Jun 20	Jul 20	Aug 20	Mean ± SD	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21	Mar 21	Jun 21	Jul 21	Aug 21	Sep 21	Mean ± SD
1.	Fateh Sagar	33	31	24	23	22	24	58	60	68	72	41.5 ± 20.45	43	31	28	29	32	52	66	74	68	56	61.7 ± 14.22
2.	Rang Sagar	2	0	2	2	0	2	6	6	8	4	3.2 ± 2.70	3	1	0	2	2	4	4	8	6	4	3.6 ± 2.50
3.	Pichola Lake	32	22	21	19	20	22	48	57	60	64	36.5 ± 18.62	30	22	21	23	23	36	48	50	54	39	37.9 ± 16.32
4.	Ayad River	18	16	18	17	15	18	28	42	48	52	27.2 ± 14.53	22	19	18	18	17	24	32	48	46	24	26.8 ± 11.52
5.	Goverdhan Sagar Lake	21	12	12	10	10	12	22	28	34	38	19.9 ± 10.44	14	8	8	7	8	12	18	26	31	16	15.4 ± 8.53
6.	RCA Campus	10	10	12	12	10	11	30	27	32	28	18.2 ± 9.92	8	10	8	8	10	14	19	24	20	14	13.5 ± 5.76
7.	MLSU Campus	21	24	22	20	22	20	47	43	48	56	32.3 ± 14.34	23	22	20	20	20	28	42	46	44	26	30.1 ± 11.28
8.	Sajjangarh Park	15	16	16	14	14	16	39	52	58	46	28.6 ± 17.98	17	14	16	15	16	30	37	32	34	25	23.9 ± 9.10
9.	Sukhadia Memorial Park	6	3	4	4	3	3	5	8	6	8	5 ± 1.94	2	0	1	0	2	4	6	4	6	5	3 ± 2.31
10.	Gulab Bagh	14	10	8	9	8	8	12	22	26	28	14.5 ± 7.85	16	12	12	8	10	16	22	30	38	27	19.1 ± 9.85

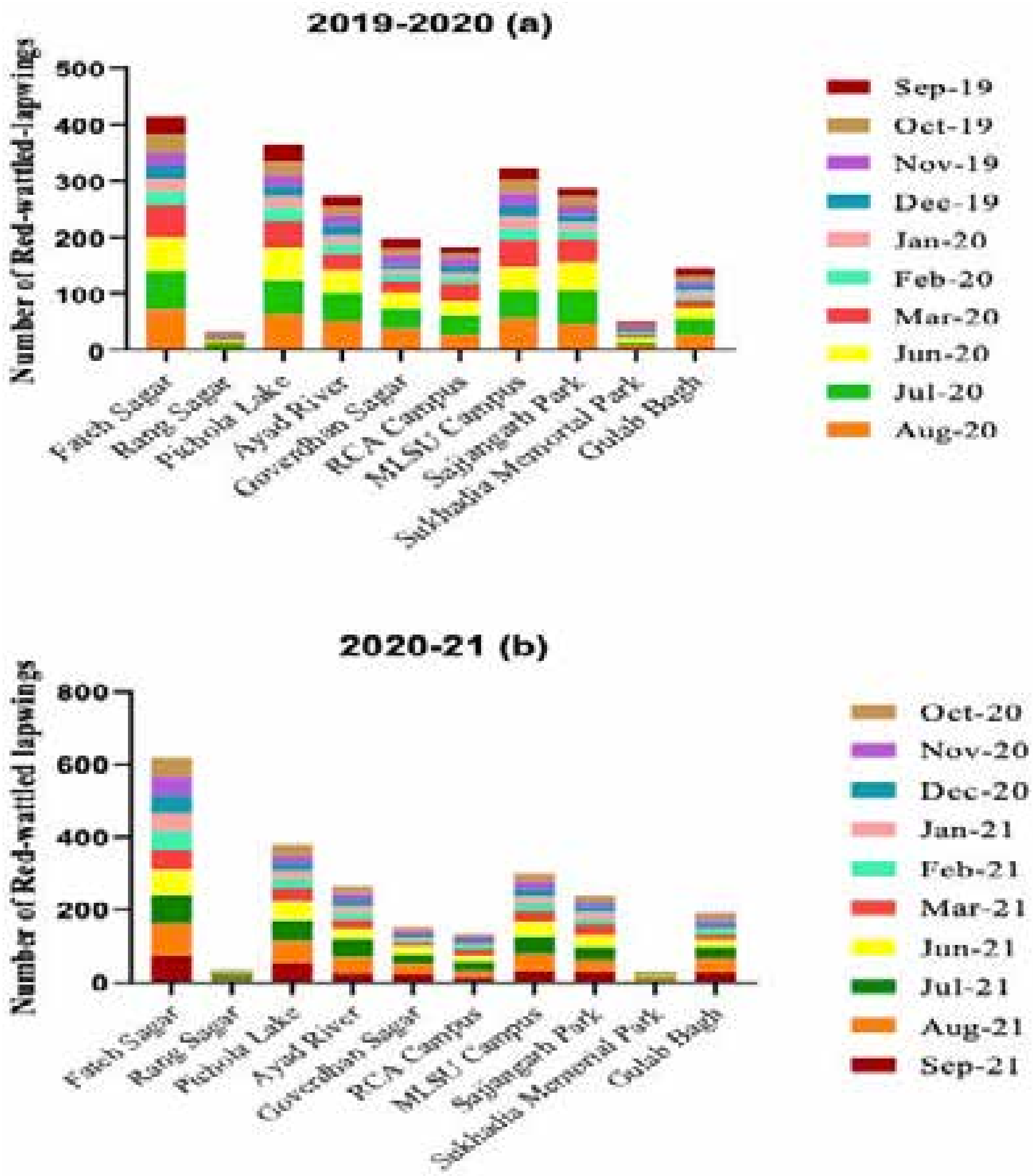

Figure 1. Population status of Red-wattled Lapwings at different locations of Udaipur City in various months during the study periods: a—2019–2020 | b—2020–2021.

RESULTS

During the current study, 2269 (Mean value = 226.9) Red-wattled Lapwings were observed in the period from September 2019 to August 2020, while 2350 (Mean value = 235) lapwings were recorded during the period between October 2020 and September 2021.

Maximum population of Red-wattled Lapwing was found at Lake Fateh Sagar (41.5 ± 20.45) and minimum at Rang Sagar Lake (3.2 ± 2.7) during the observation period from 2019 to 2020. The statistical analysis of data presented in Table 1 revealed that the variation of the population at diverse locations (F = 32.37; p <0.0001; df = 9) was slightly more significant than that with different months (F = 26.02; p <0.0001; df = 8). The highest population was recorded in August 2020 (39.60 ± 22.72) while the lowest was in January 2020 (12.4 ± 7.63) (Figure 1a).

During the study period from 2020 to 2021, the highest population occurred at Fateh Sagar (61.70 ± 14.22) while the lowest population was found at Sukhadia Memorial Park (3.00 ± 2.31) (Figure 1b). On performing ANOVA for Table 1, the result showed that the population varied highly significantly at various sites (F = 105.30; p <0.0001; df = 9) compared to different months (F = 26.71; p <0.0001; df = 9). The highest population was observed in August 2021 (37.70 ± 24.91) while the least was in January 2021 (15.10 ± 14.45).

Combining the results of both years, the highest population was found at Lake Fateh Sagar (51.47 ± 14.28) and the lowest at Rang Sagar Lake (3.4 ± 0.28).

Further, the varied habitats and seasons on the population status of Red-wattled Lapwings were also analyzed (Figure 2). The Red-wattled Lapwings existed in diverse habitats (Image 2). It was found that the nature of the habitat produced a highly significant impact on the population (F = 67.62; p <0.0001; df = 6). The highest population occurred in wetlands (50 ± 13.34) followed by crop fields (21.33 ± 9.85), protected areas encompassing scrub forests and shrubland (20 ± 7.82), grasslands (18.83 ± 9.35), institutional green spaces (18.33 ± 8.11), urban parks or gardens (15.83 ± 7.49) and constructed buildings, footpaths & roads (11.5 ± 3.39) (Table 2). Although the wetland was the most preferred habitat, the lowest numbers of lapwings were recorded at Rang Sagar Lake. This may be due to the indiscriminate dumping of garbage and sewage in the lake as well as excessive human disturbances near this wetland. Conversely, the presence of these birds near human habitation such as urban parks and constructed buildings indicates that these birds have adapted well to the anthropogenic pressure.

Further, variation of the population across different habitats in diverse seasons also showed significance (F = 33.92; p <0.0001; df = 8). The overall highest population of lapwings in various seasons was recorded in monsoon (33.14 ± 1.11) followed by summer (19.86 ± 1.21) and winter (14.57 ± 0.61) during the study periods (Table 2). On the contrary, the number of individuals was higher in the wetlands in the summer season.

The activity patterns of Red-wattled Lapwings studied during the periods 2019–2020 and 2020–2021 did not show any significant variation by performing Mann Whitney U-test (U = 39; p = 0.9314). A two-way ANOVA revealed that the percentage of each activity varied highly significantly across different months (F = 218.4; p <0.0001; df = 8) but the percentage of all activities in a particular month did not vary considerably (F = 0.0072; p >0.9999; df = 8) in 2019–2020 (Table 3). For the 2020–2021 study period, again the percentage of each activity varied significantly across different months (F = 182.6; p <0.0001; df = 8) but the percentage of all activities in a particular month showed insignificant variation (F = 0.0019; p> 0.9999; df = 8) (Table 3).

The analysis of activity patterns during the breeding and non-breeding season showed that there were no

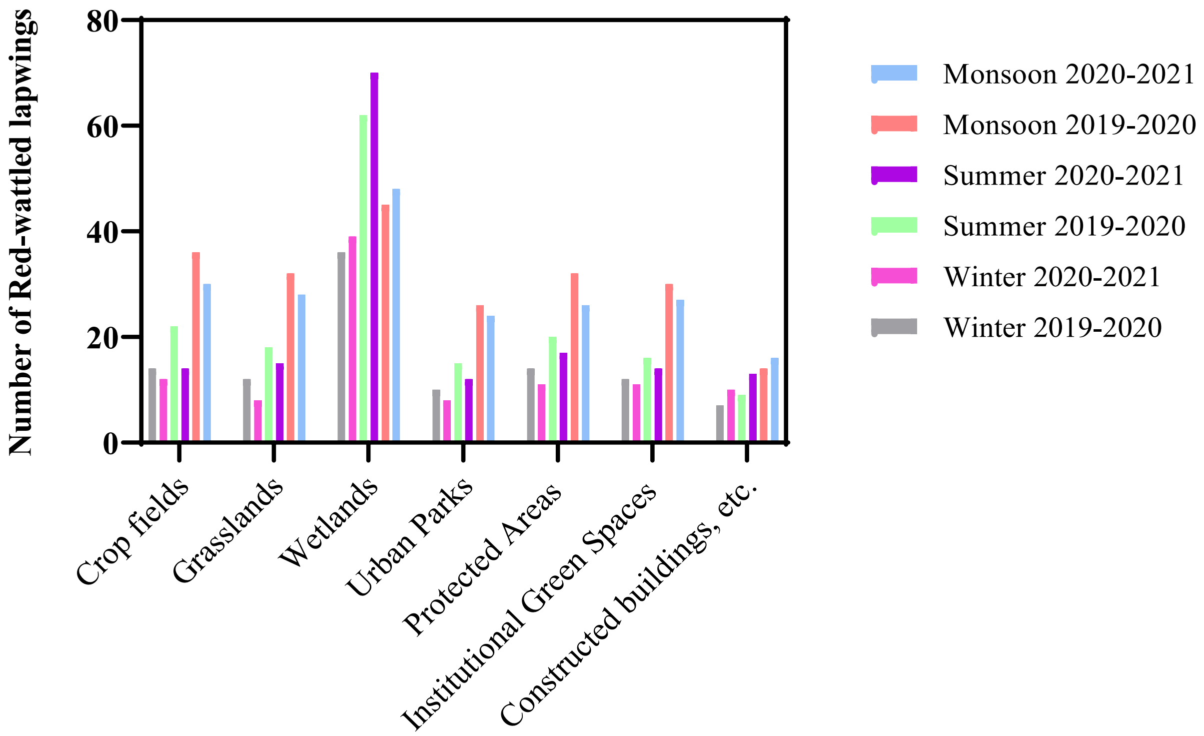

Figure 2. Population distribution of Red-wattled Lapwings across various habitats in Udaipur City during winter, summer, and monsoon seasons in 2019–2020 and 2020–2021.

Image 2. Red-wattled Lapwings thriving across different habitats in Udaipur City: a—Crop-field | b—Grassland | c—Wetland (Lake) | d—Wetland (River) | e—Protected area | f—Urban Park | g—Institutional green spaces | h—University Campus' fountain area | i—Embankment | j—Footpath | k—Building's rooftop| l—Vacant site | m—Roadside. © Sahil Gupta.

Table 2. Population distribution of *Vanellus indicus* across different habitats of Udaipur City in various seasons during 2019–2021.

	Habitats	Winter Season		Summer Season		Monsoon Season		Total	
		2019–2020	2020–2021	2019–2020	2020–2021	2019–2020	2020–2021	2019–2020	2020–2021
1.	Crop fields	14	12	22	14	36	30	72	56
2.	Grasslands	12	8	18	15	32	28	62	51
3.	Wetlands	36	39	62	70	45	48	143	157
4.	Urban Parks (Gardens)	10	8	15	12	26	24	51	44
5.	Protected Areas (Scrub Forests and shrubland)	14	11	20	17	32	26	66	54
6.	Institutional Green Spaces	12	11	16	14	30	27	58	52
7.	Constructed buildings, roads, footpaths, etc.	7	10	9	13	14	16	30	39
Total individuals in different seasons		105	99	162	155	215	199	482	453

Table 3. Activities of Red-wattled Lapwings during different months in the periods 2019–2020 and 2020–2021.

	Activity	Relative Percentage of Activities (2019-2020)										Relative Percentage of Activities (2020-2021)									
		Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	Aug 20	Mean ± SD	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21	Jun 21	Jul 21	Aug 21	Sep 21	Mean ± SD
1	Locomotion	18.19	21.68	22.08	22.01	23.21	21.72	17.64	16.82	16.74	20.01 ± 2.59	21.13	22.78	22.11	23.27	21.12	15.01	16.54	16.65	16.98	19.51 ± 3.17
2	Foraging	12.86	15.12	15.19	15.08	15.23	15.7	10.93	12.97	12.82	13.99 ± 1.64	15.07	15.29	15.38	15.98	15.11	12.06	11.91	10.94	11.77	13.72 ± 1.98
3	Vigilance	32.28	31.03	30.45	30.23	29.08	30.8	40.87	41.05	40.24	34.00 ± 5.11	30.83	30.96	29.5	30.32	30.98	42.07	40.44	41.95	40.89	35.33 ± 5.74
4	Maintenance	15.84	15.28	15.81	15.88	16.32	15.43	13.24	12.06	12.12	14.66 ± 1.70	16.12	15.68	16.18	15.48	15.29	13.08	12.96	12.95	12.56	14.48 ± 1.54
5	Defense	1.17	1.19	1.08	1.26	0.98	1.14	1.98	2.04	1.27	1.34 ± 0.39	1.16	1.17	1.21	1.15	0.99	2.01	2.06	1.9	1.48	1.46 ± 0.42
6	Vocalization	2.38	1.95	2.05	1.99	1.66	1.72	2.6	2.66	2.42	2.16 ± 0.37	1.92	2.12	1.96	1.79	1.71	2.75	2.85	2.93	2.08	2.23 ± 0.48
7	Social interactions	0.73	0.63	0.67	0.68	0.7	0.82	0.72	0.66	0.74	0.70 ± 0.05	0.69	0.68	0.65	0.72	0.68	0.69	0.67	0.7	0.71	0.69 ± 0.02
8	Inactivity	11.67	9.68	10.02	9.78	10.06	10.72	8.88	8.62	10.33	9.97 ± 0.92	9.82	9.27	9.87	9.23	10.91	9.23	9.38	9.14	11.19	9.78 ± 0.77
9	Miscellaneous	4.88	3.44	2.65	3.17	2.76	3.67	3.14	3.12	3.32	3.35 ± 0.65	3.26	2.05	3.14	3.06	3.21	3.1	3.19	2.84	2.34	2.91 ± 0.43

significant differences in the behaviours during both seasons (Figure 3) (Mann Whitney U = 40; p >0.9999). During the breeding season, vigilance (40.31%), locomotion (16.89%), maintenance (12.73%), and foraging (12.22%) were the main activities followed by inactivity (9.72%), miscellaneous activities (3.14%), vocalization (2.14%), defense (2.07%), and social interactions (0.78%) (Table 4). A two-way ANOVA at different periods of the day revealed that each activity varied significantly at different times during the breeding season (F = 194.5; p <0.0001; df = 8) but there was no major difference in all activities performed in a particular period (F = 2.29; p = 0.0712; df = 5) (Table 4, Figure 4a).

The major activities of Red-wattled Lapwing during the non-breeding season were vigilance (30.66%) followed by locomotion (21.21%), feeding (16.17), maintenance (15.19%), and other activities such as inactivity (10.02%), miscellaneous (2.74%), defense (1.36%), vocalizations (1.94%), and social interactions (0.71%) (Table 4). Multiple t-tests for activities in breeding and non-breeding seasons revealed that significant differences exist in vigilance (t ratio = 5.571; p = 0.000182; df = 10; q-value = 0.000645) and defense (t ratio = 6.587; p = 0.000062; df = 10; q-value = 0.000437) (Table 4). In the non-breeding season, each activity at different periods of the day (F = 230.6; p <0.0001; df = 8), as well as activities performed in a particular period (F = 2.29; p = 0.0712; df = 5), showed noteworthy variation, the former being far more significant than the latter (Table 4, Figure 4b).

Overall, the results show that amongst all the

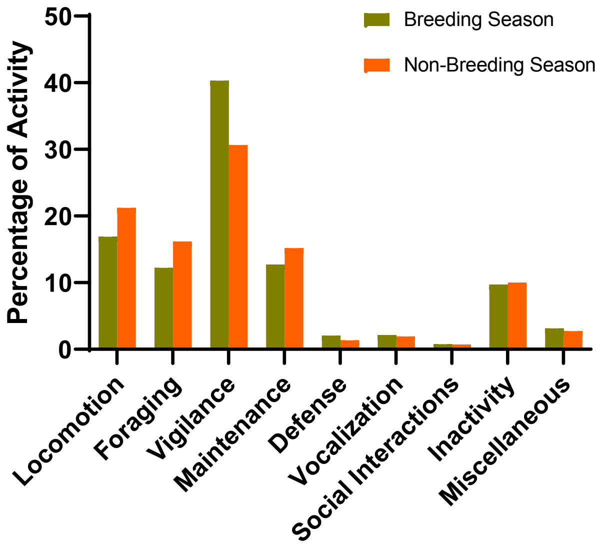

Figure 3. Percentage of activities of Red-wattled Lapwings across breeding and non-breeding seasons.

activities displayed during the study period, the Red-wattled Lapwing showed the highest level of vigilance activity (alert posture/crouched in alert, neck usually extended forward with upright posture and horizontal bill) throughout the months of breeding as well as non-breeding seasons. Locomotion (walking, running, and flying) was the second most performed activity. Feeding (foraging- foraging-stop-run-peck, foot stirring as well as prey handling) and maintenance (preening, bathing, scratching, stretching, grooming legs with bill, and shaking the plumage) were the next most important activities. It was found that during the non-breeding season, the birds were less vigilant and spent more time feeding, especially during morning and late afternoon.

Red-wattled Lapwings were often observed standing still or resting during the study schedule. It was more prominent during the evening hour (1700–1800 h). Miscellaneous activities such as disheveling of feathers, tail shaking, stomping the ground, head lowering, spreading wings, and defecating were also demonstrated by Red-wattled Lapwing during the investigation.

The defense strategies adopted by Red-wattled Lapwing included distraction displays like injury feigning, crouched run, false brooding, false feeding, aggression and mobbing, escape behaviour, and swooping. The lapwings showed defense behaviour and uttered loud alarm calls more during the breeding season (March to September) to protect their nests and young ones from predators.

Red wattled-Lapwings were also spotted interacting among themselves as well as found in association with birds like Cattle Egret *Bubulcus ibis*, Little Cormorant *Microcarbo niger*, Red-naped Ibis *Pseudibis papillosa*, Painted Stork *Mycteria leucocephala*, Asian Openbill Stork *Anastomus oscitans*, Little Grebe *Tachybaptus ruficollis*, and mammals like cattle. The lapwings were frequently seen roosting with birds like cormorants and alerting other bird species by making alarm calls. Two intra- and one inter-specific conflicts were observed. The intra-specific conflicts were for territory and mate while the interspecific fight with Cattle Egret *Bubulcus ibis* was for food. We observed that when predators like crows or dogs were sighted, lapwings showed active defense behaviour, especially during the breeding season. We also documented that during the non-breeding season, a foraging lapwing was not found to be scared in the presence of a dog who was at less than 1 m. Our observations revealed that when humans were at 5 m or less, the Red-wattled Lapwings were often observed uttering loud calls, running, and on approaching closer, the birds often flew away. Thus, a diverse range of behaviour of Red-wattled Lapwings was observed during our study.

DISCUSSIONS

Population Studies on Red-wattled Lapwings

The overall highest population was found at Fateh Sagar Lake while the lowest was recorded at Rang Sagar Lake, which could probably be ascribed to several factors such as high level of human disturbance, indiscriminate dumping of garbage and poor sewage management of Rang Sagar Lake (Pillai 2000) rendering it one of the most polluted lakes of Udaipur city and unsuitable habitat for lapwings. The breeding season of Red-wattled Lapwing extends from March to August (Kumar et al. 2005). The occurrence of the highest number of Red-wattled Lapwings in August and the lowest number of lapwings in January is probably because August and January coincide with the breeding and non-breeding seasons of these birds, respectively.

Red-wattled Lapwings usually prefer open areas near water resources (Wiersma & Kirwan 2019). In our surveys the birds were found over a wide range of open habitats such as croplands, grasslands, wetlands, protected areas, institutional green spaces, constructed buildings, roads, footpaths, etc. which corroborate with earlier observations (Ali 1996; del Hoyo et al. 1996; Ali & Ripley 2001; Narwade et al. 2010; Sethi et al. 2011; Muralidhar & Barve 2013). The habitat preference of lapwings reveals that the proximity of water and food

Table 4. Percentage of activities of Red-wattled Lapwings at a different period of the day during the breeding and non-breeding seasons.

	Activity	Period of day (hours) during Breeding Season						Total Percentage	Period of day (hours) during Non-Breeding Season						Total Percentage
		0701–0800	0801–0900	0901–1000	1201–1300	1601–1700	1701–1800		0701–0800	0801-0900	0901-1000	1201-1300	1601-1700	1701-1800	
1	Locomotion	3.52	3.69	3.21	2.04	2.23	2.2	16.89	3.56	3.8	3.95	3.12	3.74	3.04	21.21
2	Foraging	2.06	2.62	2.29	1.46	2.16	1.63	12.22	2.16	3.24	3.47	2.1	2.98	2.12	16.17
3	Vigilance	6.72	7.14	7.03	6.38	6.93	6.11	40.31	4.93	5.52	5.68	4.44	5.57	4.52	30.66
4	Maintenance	1.37	2.64	2.66	2.76	1.78	1.52	12.73	2.38	2.68	2.78	2.42	2.56	2.37	15.19
5	Defense	0.37	0.39	0.36	0.32	0.35	0.28	2.07	0.2	0.22	0.25	0.24	0.21	0.24	1.36
6	Vocalization	0.38	0.37	0.35	0.29	0.36	0.39	2.14	0.33	0.35	0.34	0.31	0.32	0.29	1.94
7	Social interactions	0.09	0.11	0.23	0.17	0.1	0.08	0.78	0.08	0.14	0.17	0.15	0.11	0.06	0.71
8	Inactivity	1.62	1.42	1.39	1.73	1.67	1.89	9.72	1.69	1.49	1.45	1.72	1.64	2.03	10.02
9	Miscellaneous	0.5	0.57	0.59	0.48	0.56	0.46	3.14	0.46	0.48	0.49	0.44	0.45	0.42	2.74

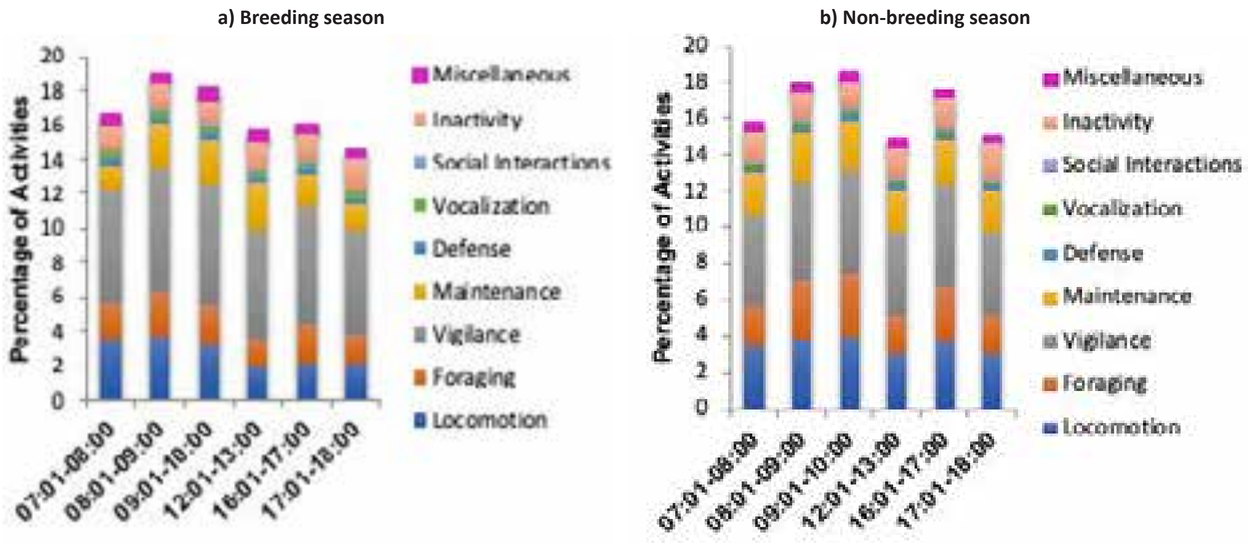

Figure 4. Percentage of activities of Red-wattled Lapwings at different hours of the day during: a—breeding season | b—non-breeding season.

resources, as well as the level of disturbance, play key factors in deciding the dwelling sites of these birds. This correlates with previous studies on shorebirds, waders, and other terrestrial birds (Smith et al. 2007; Verma & Murmu 2015). Further, the presence of these birds near human habitations such as urban parks and construction sites confirms that these birds have adapted very well to anthropogenic pressures.

The effect of seasonal variation on the distribution of Red-wattled Lapwings across different habitats of Udaipur City reveals that the monsoon season is the most favorable season for these birds followed by summer and winter. The highest population of birds during monsoon could be attributed to the abundance of food (in the form of insects) and water (Delgado & Moreira 2010; Franca et al. 2020). Red-wattled Lapwings are also known to feed on food grains (Babi 1987). Therefore, the high population of Red-wattled Lapwings in croplands during the monsoon could be attributed to the presence of harvest of maize and sorghum (Jat et al. 2004; Lin 2005). Also, during monsoon, growth of wild grass and vegetation increases across different habitats like protected areas, grasslands, institutional green spaces, urban parks or gardens, along roads, and empty plots, thus providing shelter along with insects as food to lapwings.

The wetlands were the most preferred sites during all seasons. However, unlike other habitats where the lapwings' population was higher during monsoon, at wetlands the trend was reversed, the population was lesser than that in summer. This is because during monsoon due to rain, the water level increases thereby flooding the islands of wetlands (Kushlan 1981; Chaudhury & Koli 2018). So, during monsoon, the Red-wattled Lapwings were mainly encountered on the embankment of the wetlands and not on the islands. The highest population of lapwings was recorded at the wetlands during summer (breeding season) because the shallow wetlands serve as breeding as well as feeding grounds for these birds. The most preferred site of lapwings during winter was also shallow wetlands, this is perhaps due to decreased water level, the wetland serves as feeding as well as social interactions grounds for the birds (Chaudhury &Koli 2018).

Activity Patterns

The investigation of the activity pattern of Red-wattled Lapwings in the present study revealed that a major part of their routine includes vigilance, locomotion, feeding and maintenance. Similar prominence of the above-mentioned activities has also been noted in other species of lapwings such as the Southern Lapwing *Vanellus chilenesis* (Maruyama et al. 2010) and River Lapwing *Vanellus duvaucelii* (Mishra et al. 2018). This confirms the active and vigilant nature of lapwings. During the study, it was observed that lapwings were vigilant during both breeding and non-breeding seasons and different periods from morning to evening. The percentage of vigilance was higher in the breeding season than in the non-breeding season. This could be due to the ground/shallow feeding as well as ground-nesting nature of the bird, which requires constant vigil against any predator or other risk factors for their enhanced survival (Lendrem 1986; Walters 1990).

Locomotion was the second most recorded activity. Locomotion is an important activity of birds that helps them to move from one place to another in search of food, water, shelter, nesting sites, and even as defense (escape) to move away from potential threats.

Feeding and maintenance were the next most visible activities of Red-wattled Lapwings. Maintenance is an imperative activity that contributes to the fitness of birds and keeps away parasites (Bush & Clayton 2018). This is perhaps because as reported in certain birds, ritualized preening has become part of courtship displays performed during breeding (Howe 1975) while in some birds, the preening oil is used to attract mates (Johansson & Jones 2007; Hirao et al. 2009).

The other behaviours displayed by Red-wattled Lapwings included defense, vocalization, social interactions, inactivity, and miscellaneous activities. Inactivity (sleeping, standing, or resting) provides them rest and helps in conserving energy (Maruyama et al. 2010).

The birds of the Charadriidae family including Red-wattled Lapwings are known for their characteristic defense strategies and vocalizations (Kalsi & Khera 1987; Walters 1990; Mishra & Kumar 2022). Vocalizations are an important part and parcel of their day-to-day activities. Though calls are less prominent than vigilance, feeding, locomotion, and maintenance activities these are quite an important mode of communication in lapwings.

CONCLUSION

The study suggests that Red-wattled Lapwings thrive across different habitats in Udaipur city throughout all seasons, with monsoon being the most favoured season. The primary habitats of these birds were found to be wetlands due to the presence of ample food and water resources. However, the lowest occurrence of lapwings in Rang Sagar Lake indicates that high level of disturbance and water pollution are anthropogenically induced threats to these birds. The study also revealed that breeding and non-breeding seasons did not produce a significant impact on the activity patterns of lapwings. Moreover, these birds are highly vigilant and vocal and display a broad range of activity patterns including feeding, locomotion, maintenance, defense, social interactions, resting, and other miscellaneous activities which supports their survival.

Overall, it can be ascertained from the present study that the availability of wide-ranging habitats, abundant supply of food and water, and highly active defense techniques of Red-wattled Lapwings have helped these birds to adapt to the growing anthropogenic pressure and there is no immediate threat to the population of Red-wattled Lapwings in Udaipur city. However, habitat destruction through pollution and ever-increasing human activities can cause a decline in their population in the future. The following measures may be helpful to conserve habitats of Red-wattled Lapwing:

1. Carrying out extensive population surveys of Red-wattled Lapwings.
2. Satellite monitoring of birds' habitats to keep track of factors that may be a threat to their survival.
3. A strict ban should be imposed on the discharge of untreated industrial effluents, sewage, microplastics, medical waste, and garbage in wetlands.
4. The use of motor boats that cause oil spillage must be prohibited.
5. Restricting vehicles and night tourism around

lakes and protected areas.

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Appendix I. GPS coordinates of major study sites.

	Main Sites/Locations	Habitats	GPS Coordinates
1.	Fateh Sagar	Wetland, crop-fields, grasslands and constructed buildings, roads and footpaths	24.601°N, 73.674°E
2.	Rang Sagar	Wetland and constructed buildings, roads and footpaths	24.584°N, 73.679° E
3.	Pichola Lake	Wetland and constructed buildings, roads and footpaths	24.572°N, 73.678°E
4.	Ayad River	Wetland, crop-fields, grasslands and constructed buildings, roads and footpaths	24.606°N, 73.696°E
5.	Goverdhan Sagar	Wetland, grasslands and constructed buildings, roads and footpaths	24.543°N, 73.683°E
6.	RCA Campus	Crop-fields and institutional green spaces	24.580°N, 73.702°E
7.	MLSU Campus	Institutional green spaces, crop-fields, grasslands and constructed buildings, roads and footpaths	24.594°N, 73.731°E
8.	Sajjangarh Biological Park	Protected areas and grasslands	24.591°N, 73.652°E
9.	Sukhadia Memorial Park	Urban Park	24.585°N, 73.709°E
10.	Gulab Bagh	Protected areas and urban park	24.572°N, 73.692°E

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COMMUNICATION

Notes on nesting behavior of Yellow-footed Green Pigeon *Treron phoenicopterus* (Latham, 1790) in Aligarh Muslim University campus and its surroundings, Uttar Pradesh, India

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Abstract: The nesting behavior of the Yellow-footed Green Pigeon *Treron phoenicopterus* was observed during its breeding season in 2021 in an urban region encompassing the Aligarh Muslim University Campus and the surrounding areas. Data were collected by searching nests in the study area. The breeding season for the species in the study sites begins in March and re-nesting is attempted even in July. A total of 31 nests were found on 24 trees belonging to eight species. The analysis of nest site characteristics revealed that *Millingtonia hortensis*, *Azadirachta indica*, and *Dalbergia sissoo* were the most important nest tree species, accounting for 69% of the identified nests during the study period. These findings contribute to our understanding of the nesting behavior of the Yellow-footed Green Pigeon in an urban environment and have implications for its conservation and management.

Keywords: Aligarh Fort, canopy, columbidae, incubation, mating season, nest site characteristics, squabs, urban region.

Hindi: हरियल (ट्रेरॉन फोनीकोप्टेरस) का घोंसला बनाने का व्यवहार 2021 में इसके प्रजनन के मौसम के दौरान देखा गया था। एक शहरी क्षेत्र में जिसमें अलीगढ़ मुस्लिम विश्वविद्यालय परिसर और आसपास के क्षेत्र शामिल हैं। घोंसले खोजकर डेटा एकत्र किया गया। अध्ययन क्षेत्र में. अध्ययन स्थलों में प्रजातियों के लिए प्रजनन का मौसम मार्च में शुरू होता है और जुलाई में भी पुन: घोंसले बनाने का प्रयास किया जाता है। कुल आठ प्रजातियों के 24 पेड़ों पर 31 घोंसले पाए गए। घोंसला स्थल की विशेषताओं के विश्लेषण से पता चला कि नीम चमेली, नीम, और शीशम सबसे महत्वपूर्ण घोंसला वृक्ष प्रजातियाँ थीं, जो इस दौरान पहचाने गए घोंसलों में से 69% के लिए जिम्मेदार थीं। ये अनुसंधान के परिणाम हमें शहरी पर्यावरण में हरियल के घोंसला बनाने का व्यवहार की समझ में योगदान करते हैं और इसके संरक्षण और प्रबंधन के लिए प्रासंगिकताएँ रखते हैं।

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Author contributions: AMM undertook field surveys, noted behavioral data, took images in the field, collected the literature for manuscript preparation and wrote the manuscript. SK designed and planned the study including interpretation of the data. SK checked the manuscript and provided inputs for improvements.

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ज्ञान-विज्ञान विमुक्तये

INTRODUCTION

The Columbidae family is one of the world's most threatened families. Despite its widespread distribution, the family, which contains pigeons and doves worldwide has received little conservation attention; is considered to have 369 species, 16 of whom are extinct, and one is extinct in the wild (the Socorro Dove *Zenaida graysoni*) (Birdlife International 2020). Thirty-three species of Columbidae have a distribution in India. It is most likely because it is one of a group of birds threatened by human persecution, habitat degradation, and introduced predators (Owens & Bennett 2000).

India has an incredible diversity of Columbiformes, inhabiting 33 species, including fruit pigeons (Ali & Ripley 1987; Grimmett et al. 2016). Frugivorous birds are the key functional species, performing valuable seed dispersal services and regeneration and their decline or local extinction may have severe consequences for the functioning of an ecosystem (McConkey & Drake 2002). Yellow-footed Green Pigeon is frugivorous species and is a common resident species in Aligarh district in Uttar Pradesh, where no studies have been carried out on its status, distribution, or ecology. As a result, we planned to investigate the Yellow-footed Green Pigeon nesting ecology in this area. It breeds in the Aligarh Muslim University campus and adjoining areas regularly, and the Indian Jungle Crow *Corvus macrorhynchos* and House Crow *Corvus splendens* prey on their clutches and nestlings. A few studies on Columbidae are by Bhattacharya (1994) on morphological adaptations, Somasundaram (2006) and Devi (2012) on the ecology of Nilgiri Wood Pigeon and Yellow-footed Green Pigeon, respectively, and Kour (2016) on eco-biology of some species from Jammu. Therefore, the present study was conducted to present preliminary data on the nesting behavior of Yellow-footed Green Pigeons in an urban region.

Study Area

Aligarh Muslim University is in Aligarh district in Uttar Pradesh, India, in the Ganga-Yamuna doab region. It is located at the northernmost part of the Agra division, stretching from 27.4833^{0}N to 28.0166^{0}N latitude and 77.4833^{0}E to 78.6666^{0}E longitude (Image 1). The district covers an area of 3,650 km^2 and is 130 km from Delhi. The flora in the area is dry deciduous with mostly deciduous trees in most areas. The locations of the nest and random plots at both the study sites, i.e., AMU campus (NC_i & RC_i) and Aligarh Fort (NQ_i & RQ_i) are shown in Image 2.

The study area has arid open scrub called 'Rakhs' (Champion & Seth 1968). The study region has soil known as 'usar', mesquite plantation, and agricultural terrain. *Prosopis juliflora* (a weed species from central America) dominates most forest patches, followed by *Acacia catechu, P. cineraria, P. specigera, Melia azadirach, Azadirachta indica, Cordia dichotoma, Pongamia pinnata, Syzygium cumini, Dalbergia sissoo, Butea monosperma, Acacia nilotica, Acacia leucophloea*, and *Phoenix sylvestris* (Yasmin 1995).

In central Ganga Plain, the interfluvial stretch of the Ganga and Yamuna passes through Aligarh district. Most of the principal physiographic are made out of alluvial infill. The deposition of the Ganga and Yamuna rivers significantly influences the main soil types in the district. The Aligarh Fort and AMU Campus in Aligarh city (27.9135^{0}N, 78.0782^{0}E) harbor a diverse range of flora, including exotic species that have been intentionally planted. The Aligarh Fort, now managed by the Aligarh Muslim University, serves as a botanical garden and spans over an area of 47.87 ha with an average elevation of around 200 m. The vegetation within the Fort can be classified into different types. The central plain area, covering 10.31 ha, predominantly consists of ornamental and fruit trees such as *Terminalia arjuna*, *Mangifera indica*, *Psidium guajava*, *Emblica officinalis*, *Syzigium cuminii*, *Morus alba*, *Tectona grandis*, *Bombax ceiba*, and others. Surrounding this central plantation is an elevated ridge of scrubland with eight bastions, covering 6.85 ha, featuring natural vegetation including *Azadirachra indica*, *Dalbergia sissoo*, and a dominant shrub cover of *Capparis sepiaria*. *Prosopis juliflora* is notably prominent in the ridge area of the Fort. Encircling the ridge is a 50-m-wide depression that consists of barren land, covering an area of 12.1 ha. During the monsoon season, this area is adorned with herbaceous plants, while dry seeds of these monsoon herbs are available for the rest of the year. The flora of the Fort includes various plants including shrubs, climbers, and trees. Additionally, the area is inhabited by several mammalian species, including the Indian Grey Mongoose *Herpestes edwardsii*, Jungle Cat *Felis chaus*, Indian Hare *Lepus nigricollis*, Indian Gerbil *Tatera indica*, Five-striped Palm Squirrel *Funambulus pennantii*, India Bush Rat *Golunda ellioti*, and Rhesus Monkey *Macaca mulatta*, as documented in previous studies (Qureshi 1991; Khan 1992; Khan 2014).

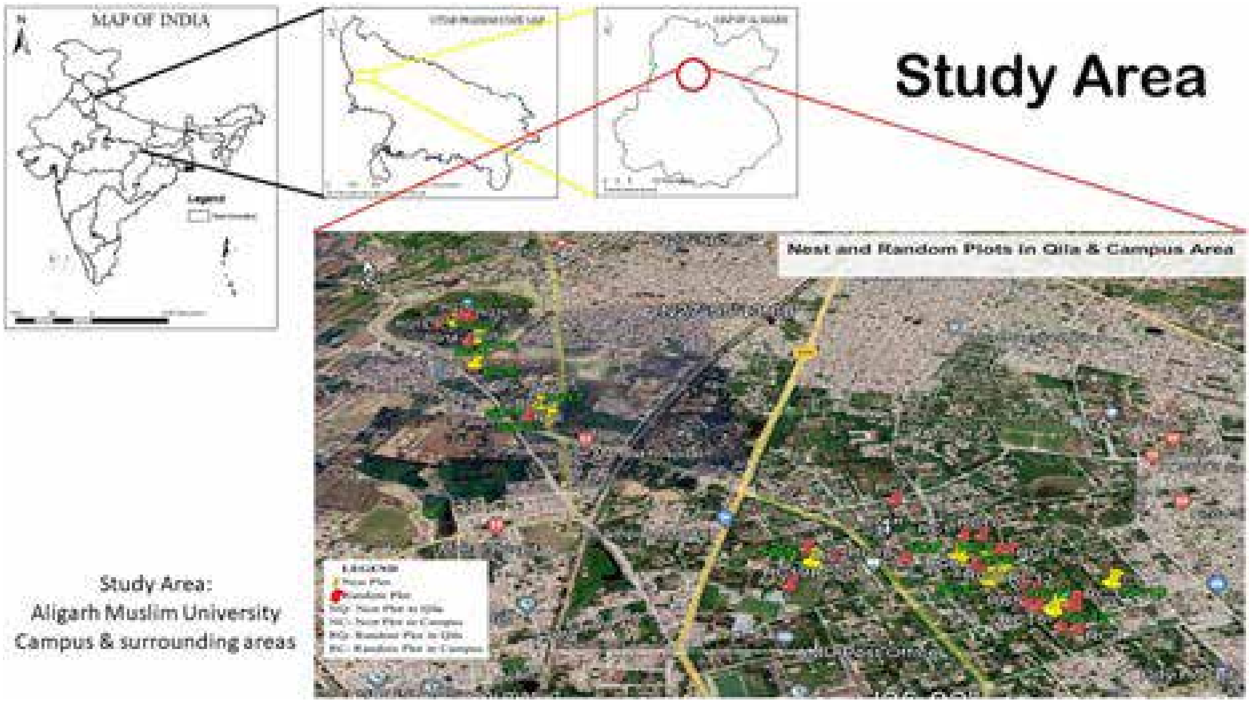

Image 1. Study area – Aligarh Muslim University Campus and Aligarh Fort.

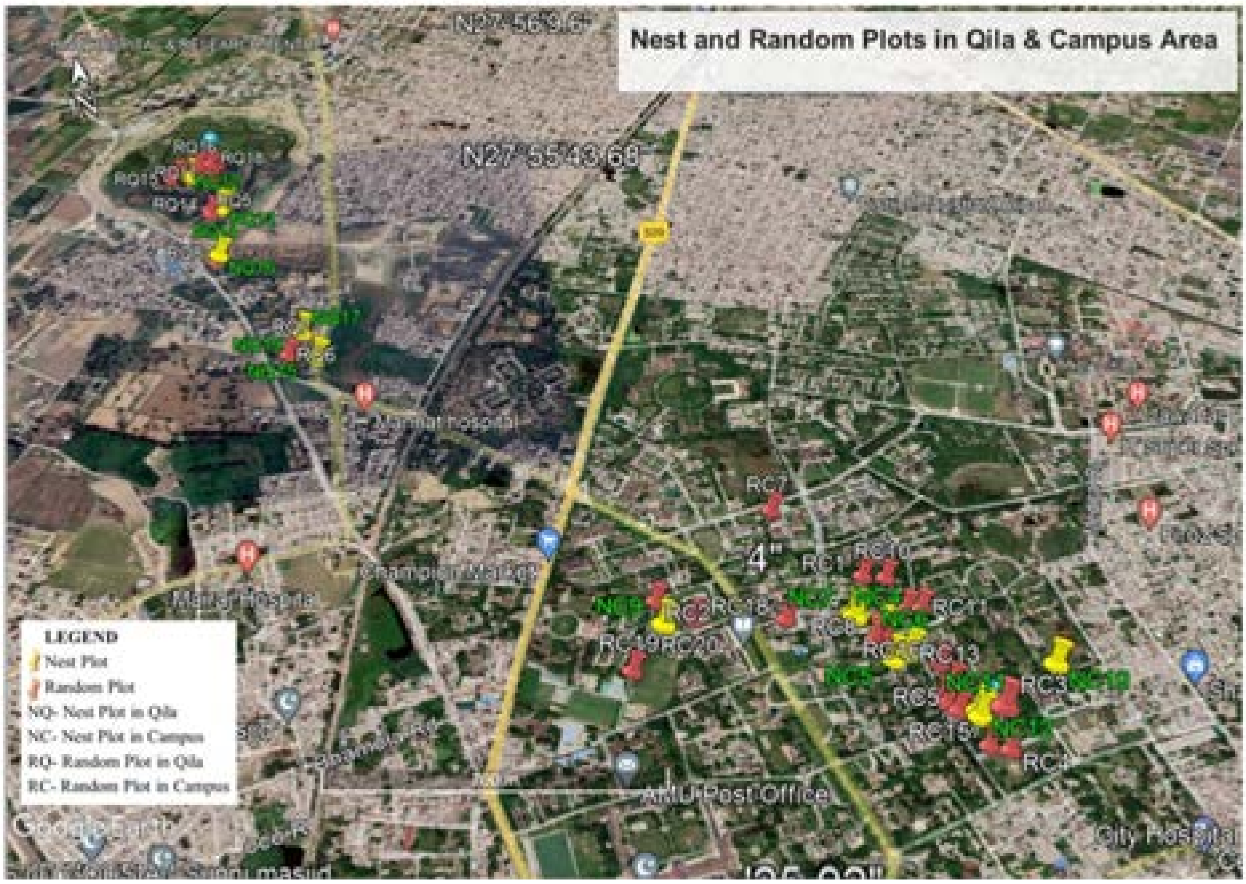

Image 2. Map depicting Nest plots (NCi and NQi) and Random Plots (RCi and RQi) located in AMU Campus and Aligarh Fort.

METHODS

Based on Devi (2012), the study focused on observing the nesting behavior of the Yellow-footed Green Pigeon during its 2021 breeding season in an urban region. The study sites included the Aligarh Muslim University (AMU) campus, Naqvi Park (27.9022° N, 78.0733° E), and the Aligarh Fort (27.9135° N, 78.0707° E). The methodology adopted by Devi (2012) aimed to understand the characteristics of the nesting sites and the factors influencing nesting site selection. To quantify the nesting environment, the methods outlined by James & Shugart (1970), subsequently refined by Mudappa & Kannan (1997), were employed. Data on nesting trees and nesting environment factors were collected and quantified. In order to detect nests of Yellow-footed Green Pigeons in the beginning of their nesting season, we largely depended on their behavioral cues such as collecting nesting material. During the mating season of Yellow-footed Green Pigeons, nest searches were conducted in the study region, and observations on nest trees and nest-site characteristics were made, following the methods used in previous studies (Gokula 2001; Devi & Saikia 2012). To ensure minimal disturbance to the nesting birds, all observations of their nesting activities were conducted from a safe distance, thus preserving the natural nesting behavior of the Yellow-footed Green Pigeon.

Observations of its nesting sites and nest site characteristics were undertaken from 10 March to 13 July 2021, when the final fledglings of active nests fledged. Once an individual or pair was sighted gathering twigs from the trees or constructing a nest, they were followed using binoculars or a camera and their nesting activities were recorded daily from 0630 h to 1130 h. A comprehensive dataset was obtained by closely observing selected nests, while additional nests were also monitored to determine the overall nesting success and gather supplementary data.

Adult birds undertaking breeding activities such as nest construction, incubation, and feeding the young in or near the nest indicated the presence of an active nest. A circular plot with a radius of 10 m was set up around each nesting tree to measure nest-site selection along with random plots which were also placed at a distance of 30–50 m from the nest plot. All characteristics were recorded in these plots as exercised in some earlier investigations (James & Shugart 1970; MacKenzie & Saely 1981; Clark et al. 1983; Sieg & Becker 1990; Liebezeit & George 2002).

Nest site and random site characteristics recorded during the study were tree number to be used subsequently for density calculations (trees/hectare), tree height (m), tree GBH (cm), basal area (m^2), the height of the first branch (m), distance from the nearest road (m), distance from nearest habitation (m), ground cover (%), shrub cover (%), canopy cover (%), canopy spread (m^3) and nest height (m). In addition, the species of nesting trees were identified and recorded. To ensure comparability and permit statistical analysis, the collected data were normalized beforehand. In the Qila (Aligarh Fort) area, the listed nest plots were labeled as NQi, while the random plots were labeled as RQi. On the other hand, in the University Campus area, the nest plots were labeled as NCi, and the random plots as RCi.

RESULTS

The Yellow-footed Green Pigeon's mating season begins in March and continues until July having re-nesting attempts towards the end of June and July. During this period, birds whose nests have been destroyed by predators seek to re-nest (Ayesha Mohammad Maslehuddin pers. obs. 31 May 2021). A total of thirty-one nests of Yellow-footed Green Pigeons

Table 1. Characteristics of nest tree species of Yellow-footed Green Pigeon in the study area.

	Tree species	Tree height (m)	Tree GBH (m)	Wood type	Foliage type	No. of nests
1	*Millingtonia hortensis*	15–25	0.20–0.55	Softwood	Deciduous	9
2	*Azadirachta indica*	10–21	0.19–1.09	Softwood	Deciduous	5
3	*Dalbergia sisso*	10–15	1.20–1.40	Hardwood	Deciduous	4
4	*Prosopis juliflora*	10–17	0.20–0.65	Softwood	Deciduous	6
5	*Holoptelea integrifolia*	17–27	0.22–1.11	Softwood	Deciduous	3
6	*Mangifera indica*	15–21	0.36–0.85	Softwood	Deciduous	2
7	*Syzygium cumini*	17–21	0.57–0.67	Softwood	Deciduous	1
8	*Bombax ceiba*	18–20	0.25–0.71	Softwood	Deciduous	1

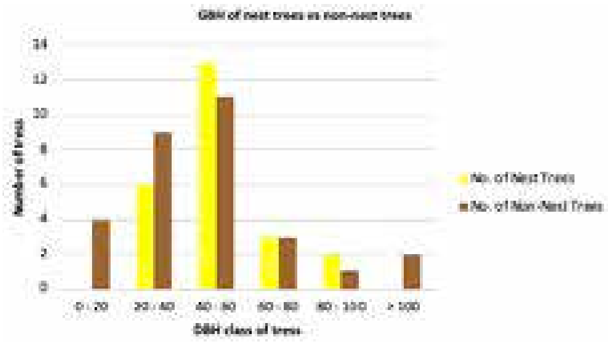

Figure 1. Girth at breast height (GBH) of nest trees and non-nest trees.

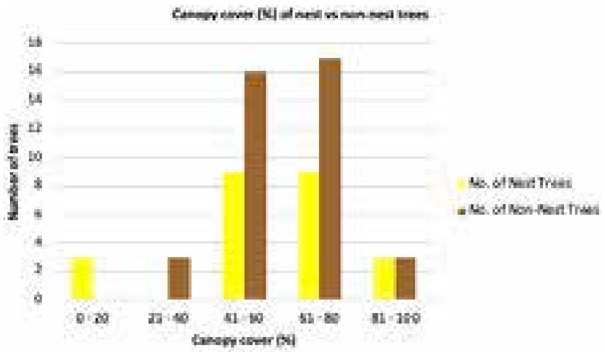

Figure 2. Canopy cover of nest trees and non-nest trees.

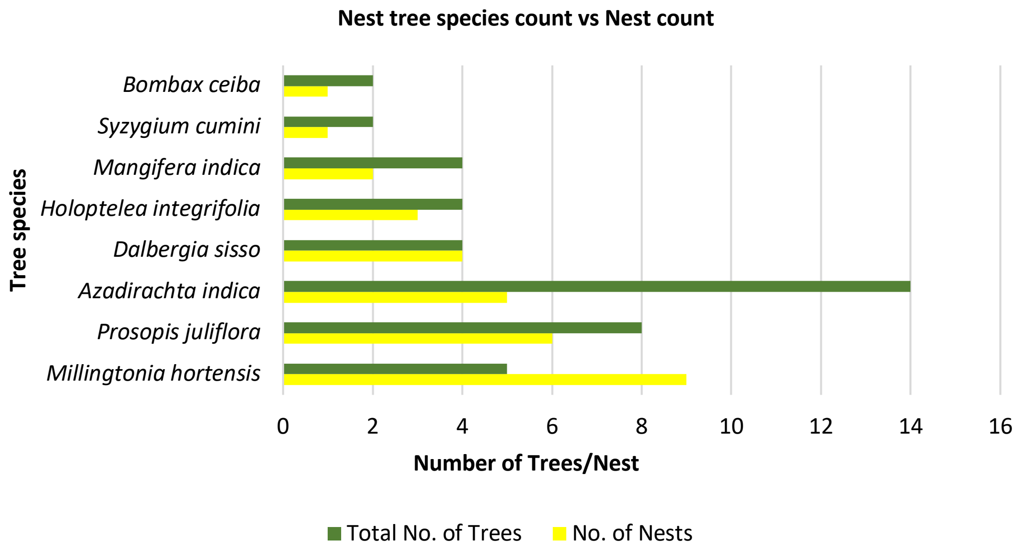

Figure 3. Total counts of nest tree species in nesting and random plots and number of nests.

were found, with 14 nests located at Aligarh Fort and 12 nests situated on the AMU campus. These nests were distributed among 26 trees in the study area. Out of the 26 nest trees, six were *Prosopis juliflora* (25%), five *Azadirachta indica* (Neem) (21%), four *Millingtonia hortensis* (Indian Cork Tree), and *Dalbergia sissoo* (Sheesham) (17%), two were *Mangifera indica* (Mango) and one each of *Holoptelea integrifolia* (Jungle Cork Tree), *Syzygium cumini* (Black Plum), and *Bombax ceiba* (Silk Cotton Tree) (Table 1).

The GBH of non-nest trees (0.46 ± 0.03) was slightly higher than that of the nest trees (0.42 ± 0.05) (Figure 1), but there was no significant difference ($t = -0.754$, $p > 0.05$) among them.

The canopy cover of non-nest trees (63.35 ± 2.26) was greater than the canopy cover of nest trees (58.37 ± 4.36) (Figure 2), and the difference was significant ($t = 17.958$, $p < 0.05$).

Tree species used for nesting by Yellow-footed Green Pigeons were *Millingtonia hortensis, Prosopis juliflora, Azadirachta indica, Dalbergia sisso, Holoptelea integrifolia, Mangifera indica, Syzygium cumini,* and *Bombax ceiba*. The number of nests on different tree species and the total number of individuals of each species, including those in the centre of random plots, are shown in Figure 3. The maximum number of nests were found on *Millingtonia hortensis.*

DISCUSSION AND CONCLUSION

The semi-natural plantations on the AMU Campus provide habitat to a wide variety of avifaunal species. The current study was one of the few attempts to acquire useful data regarding the ecology of species nesting.

Nest site characteristics show that *Millingtonia* *hortensis*, *Azadirachta indica,* and *Dalbergia sissoo* are essential nest tree species accounting for 69% of the total nest trees identified during the study period. These tree species ranged 11–25 m in height and were branched and bifurcated to provide a better place to hold the nest and a safe base for the pigeons to make their nests. Another reason was the abundance of these tree species at the study site.

The study revealed that the breeding season of Yellow-footed Green Pigeon is from late March to July in the study area. Nest building begins in early April, and they make open nests of mostly twigs (Image 3). Nests of Yellow-footed Green Pigeons are very simple in structure and made up of small twigs placed crisscrossed over one another. Both sexes were seen sharing nest building and duty of incubation, i.e., one of the breeding males or females continued to sit on the eggs while the other pair went foraging. As per observation, only one squab is hatched per nest. The duration from nest building until the fledgling left the nest was 39–44 days.

Nest building by Yellow-footed Green Pigeons was observed during the study period. Most of the nest-building activity occurred 0630–1000 h. Nest materials such as twigs were collected from dried branches of *Holoptelea integrifolia*, *Azadirachta indica*, *Tectona grandis*, *Eucalyptus citriodora*, *Syzygium cumini*, and *Casuarina equisetifolia* trees 15–30 m away from nest site by one of the mates. One of the breeding pair individuals broke suitable twigs from the branches and carried them toward the nest. The waiting individual on the tree gently arranged it into the nest securely. Also, it was observed that the individual carrying the twig never landed directly at the location where another mate was building the nest; instead, it would land on branches higher in the canopy and then move down towards the nest location cautiously. Apart from these, the frequency of nest-building trips was maximum during the 2nd and 3rd days of nesting, which gradually declined in the following days.

During the study, birds of prey such as Pariah Kites *Milvus migrans* and occasionally crows (*Corvus splendens* or *C. macrorhynchos*) were commonly seen preying on nests of Yellow-footed Green Pigeon. Some competitors like Common Mynas *Acridotheres tristis*, Eurasian Collared Dove *Streptopelia decaocto*, and Indian Palm Squirrel *Funambulus palmarum* mostly destroyed the nests; they forcefully entered the nest area of the pigeon, destroyed it and occupied the territory. Natural calamities like heavy rain and the storm destroyed most nests during the pre-hatching stage. Generally, the Yellow-footed Green Pigeons construct their nests on softwood trees, which are easily broken due to heavy rain and storm.

Association of yellow-footed Green Pigeons with the Black Drongo *Dicrurus macrocercus* during nesting season (Image 3) may be a great driver in predicting nests' success and subsequently emerging chicks. Around 40% of nests were successfully raised due to a Black Drongo nest in the vicinity of nests of Yellow-footed Green Pigeons. It has also been observed by Ali & Ripley (1987).

The success of nesting attempts by Yellow-footed Green Pigeons was determined based on the presence of hatched squabs in each nest. Of all the nests encountered, it was determined that only 35% achieved successful nesting, indicating the successful hatching of squabs. In contrast, the remaining 65% of nests were deemed unsuccessful due to their destruction by storms or abandonment caused by excessive disturbance, resulting in the absence of hatched squabs.

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Image 3. Nesting behavior of *Treron phoenicopterus* in the study area: a—Breeding pair | b—Nest building activity | c—Incubation activity | d—Nest exchange behavior of breeding pair | e—One of the parents with nestling | f—Feeding the nestling | g—One of the parents with the fledgling | h—built their nest nearby the nest of *Dicrurus macrocercus*. © Ayesha Mohammad Maslehuddin.

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Threatened Taxa

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COMMUNICATION

Observations on cooperative fishing, use of bait for hunting, propensity for marigold flowers and sentient behaviour in Mugger Crocodiles *Crocodylus palustris* (Lesson, 1831) of river Savitri at Mahad, Maharashtra, India

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Abstract: As far as animal cognition is concerned, in comparison with mammals and birds, reptiles have been underestimated and research in reptilian cognition hasn't progressed much due to this bias. Though crocodiles are generally stereotyped as lethargic and lacking social interactions except for territoriality, parental care and prey ambush, they demonstrate discrete behavioural repertoire in a variety of situations suggestive of refined cognition. The observations presented here were recorded during a long-term study on Muggers *Crocodylus palustris* of Savitri River in Maharashtra, and indicate social behaviour of remarkable acuity among Muggers to optimize foraging, which clearly hints at cooperative fishing. Also, on many occasions here, the Muggers were seen to have sticks on their snouts or lay still in the vicinity of floating twigs presumably to lure birds that desperately scouted for nesting material; though only on one occasion the unsuspecting bird was ambushed successfully. Flight initiation distances (FID) of birds that forage and nest in crocodilian habitat have been measured to assess their wariness towards crocodile's presence. We report the attraction of free ranging Muggers here to the yellow Marigold *Tagetes erecta* flowers. We also remark on apparent sentience involving a dog that was chased into the river by a pack of feral dogs, the 'aquatic refugee' having been seemingly nudged and escorted to safety of the bank by crocodiles. All these behaviours are discussed in the light of previous reports involving other crocodilian species elsewhere, to assess the cognitive faculty of this species.

Keywords: Avian wariness, cross-species empathy, group fishing, hunting lures, reptilian cognition, topical pathogens.

Marathi: सर्वसाधारणतः सरीसृप प्राण्यांच्या आकलन क्षमते विषयी गैरसमज आहे, जेणेकरून त्यांच्या व्यवहार आणि वर्तनाबद्धल संशोधकांचे दुर्लक्ष झालेले आढळते. मगर एक सुस्त प्राणी असून, ह्या प्रजाती मध्ये सामाजिक वर्तनाचा अभाव असतो अशी धारणा आहे. वास्तव्याच्या क्षेत्राचे संरक्षण, आणि अंडी व पिल्लांचा बचाव ह्या मगरींच्या दोन स्वभाव-वैशिष्ट्या व्यातिरिक्त इतर स्वभाव पैलूंचा क्वचितच अभ्यास झाला आहे. सामाजिक परस्पर-संवादाचा अभाव म्हणून रूढ केले जात असले तरी; परिष्कृत अनुभूतीचे सूचक असलेल्या विविध परिस्थितींमध्ये मगरी स्वतंत्र वर्तणुकीचा संग्रह प्रदर्शित करतात. येथे सादर केलेली निरीक्षणे महाराष्ट्रातील सावित्री नदीच्या मगरींवरील दीर्घकालीन अभ्यासा दरम्यान नोंदवली गेली आहेत. मासे एकत्रित करण्यासाठी मगरी ज्या उल्लेखनीय तीक्ष्णतेचे सामाजिक वर्तन दर्शवते, त्यात सहकार्याच्या छटा स्पष्टपणे दिसून येतात. विणीच्या हंगामात घरटी बांधण्यासाठी पक्ष्यांना लागणाऱ्या काटक्या स्वतःच्या शरीरावर ठेवून मगरी आपल्या भक्ष्याला आकर्षित करतात असे ही दिसून आले आहे. मगरींच्या सभोवताली वावरणाऱ्या विविध पक्ष्यांच्या प्रजातींचे 'उड्डाण प्रारंभ अंतर' मोजण्यात आले आहे. सावित्री नदीतील मगरींना झेंडूच्या फुलांचे खास आकर्षण आहे असे वाटते. जंगली कुत्र्यांच्या टोळीने नदीत पाठलाग केलेल्या जल-निर्वासित कुत्र्याचे मगरींनी सामूहिकरित्या केलेल्या सुटकेचे शास्त्रीय विश्लेषण हा सुद्धा ह्या शोध निबंधाचाच महत्वाचा विषय आहे.

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Author contributions: UMC has conducted and supervised field studies, collected technical literature and assisted in data collation and analysis. MRB has conceptualized the research problem, collated and analyzed data, perused pertinent literature, written and revised the research manuscript.

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INTRODUCTION

Mugger or Indian Marsh Crocodile *Crocodylus palustris* (Lesson, 1831) is a ubiquitous reptile of the Indian subcontinent, occupying freshwater habitats like rivers, lakes, and marshes (Chavan & Borkar 2022a,b); as well as man-made reservoirs and irrigation canals (Kpe'ra et al. 2014; Gurjwar & Rao 2018). This species has also adapted well to estuarine waters in India and Sri Lanka (Whitaker & Whitaker 1989; Da Silva & Lenin 2010).

On a scale of social behaviour, it is a reductionist approach to fix animals as being strictly solitary or overtly social, as every species is compelled to interact with conspecifics on its life trek for various reasons; only the scales of interaction varying in degree and frequency (Tinbergen 1953; Alexander 1974). Among vertebrates, the groups that have social aggregations and invest in parental care are generally known to display diverse and complex social behaviour. It is a largely held opinion that reptiles are solitary and aggressive, and show little display of social behaviour except that involving hierarchical assertion and defense of territory (MacLean 1990; Wilkinson et al. 2010). However, their 'non-social' status (Brattstrom 1974; Wilkinson & Huber 2012; Doody et al. 2021) is a flawed and undeserving attribute of the reptilian species. Hence such chronic neglect and bias against reptilian social behaviour merits an explanation. In fact, researchers have recorded complex reptilian behaviour of great survival as well as altruistic values (Doody 2011; Clark et al. 2012).

While this gap is emphatic, perhaps the most plausible reason for this neglect could be the bias of ethologists favouring the more colourful and vocal birds, and mammals with facial expressions that are easy to observe; as against the dull coloured reclusive reptiles that lie still and inactive for long periods (Gaston & May 1992; Kellert 1993; Pawar 2003; Chavan & Borkar 2022b). That such 'taxonomic chauvinism' has certainly delayed our understanding of reptilian behaviour is a view corroborated by Bonnet et al. (2002).

In this paper we have attempted to highlight crocodilian behaviours that hitherto have not received much attention, and could assist in cognitive assessment of this reptilian group.

Thus far, researchers have focused more on their ecology and conflict potential, and very little attention has been given to the ethology of this species. Studies on crocodilian behaviour are in its nascent stages in India, and most of their reported behaviour has been studied by observing captive animals (Clark et al. 2012; Burghardt 2013). In this paper we report definitive instances of cooperative fishing, use of hunting lures, a curious propensity of free ranging Muggers of river Savitri for Marigold *Tagetes erecta* flowers and an instance of plausible cross species empathetic behaviour involving a dog.

METHODOLOGY AND FIELD PROTOCOLS

The present study was a component of a long-term monitoring of Mugger population of Savitri River in Mahad town of Raigad district of Maharashtra, India; since 2014 (Chavan & Borkar 2022a, b). All the naturalistic observations were carried out in river stretches corresponding with four stations namely at Kemburli (18.0661°N; 73.4138°E), Mohalla (18.0725°N; 73.4188°E), Dadli (18.0697°N; 73.4311°E), and Smashaan (18.0669°N; 73.4411°E).

Muggers of Savitri River have been studied by naturalistic observations in field – without compromising on safety of researchers and territorial limits of the reptile. Crocodilian behaviour presented here has been documented by a team of five observers during every visit; between 0600 h & 1200 h and 1400 h & 1800 h, as well as night time from 1900 h to 2300 h. Observations were recorded using binoculars (Model Galileo 30 x 60) as well as photo-documented, by sitting on a bank elevation and in a boat for understanding patterns of their maintenance behaviour, as well as their interactions with conspecifics and other species. In this study we have also assessed flight initiation distance (FID) as a measure of wariness of birds towards the Mugger. A total of 26 species of birds belonging to 11 families (Table 1, Figure 1) frequenting the water and bank of this river for foraging and nesting were observed for their FID vis a vis the movement of the Mugger, the apex predator here. FID was calculated as a mean value in meters up to which the bird would approach the crocodile without hesitation, or distance at which any visible movement of the crocodile would trigger an escape flight in the bird being observed. Focused attention was given to the Mugger's active foraging activity through all seasons and also their passive hunting strategies. The affinity of these reptiles for 'floating objects' in the river such as flowers, was carefully documented. Photographs and videos were captured by digital and DSLR cameras.

Table 1. Flight initiation distance (FID) as a measure of wariness of birds that share habitat with Muggers of Savitri River, Mahad, Maharashtra.

	Family & common name of the bird	Scientific name	Nesting	Foraging	Feeding guild	Habit	Mean FID ± SE
I	**Ardeidae**						
1	Western Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	Yes	Yes	IN	Invertebrates, mostly insects	1.12 ± 0.22
2	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	No	Yes	PI/CV/IN	Fish, molluscs, crustaceans, insects	0.84 ± 0.15
3	Intermediate Egret	*Ardea intermedia* (Wagler, 1827)	No	Yes	PI/CV	Fish, crustaceans	2.2 ± 0.34
4	Great Egret	*Ardea alba* (Linnaeus, 1758)	No	Yes	PI	Fish	2.06 ± 0.17
5	Purple Heron	*Ardea purpurea* manilensis (Meyen, 1834)	No	Yes	PI	Fish	2.26 ± 0.10
6	Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	No	Yes	PI/CV	Fish, crabs	2.66 ± 0.09
7	Indian Pond heron	*Ardeola grayii* (Sykes, 1832)	Yes	Yes	PI	Fish	0.36 ± 0.04
8	Black-crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	Yes	Yes	PI/IN	Fish, insects	0.44 ± 0.05
II	**Threskiornithidae**						
9	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	No	Yes	IN/GR	Insects, grains	4.06 ± 0.04
10	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	No	Yes	PI/CV	Fish, snails	4.36 ± 0.08
11	Eurasian Spoonbill	*Platalea leucorodia* (Linnaeus, 1758)	No	Yes	CV/IN/PI	Crustaceans, insects, fish	0.9 ± 0.19
III	**Ciconiidae**						
12	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	No	Yes	PI/CV/IN	Fish, crustaceans, small reptiles, insects	7.7 ± 0.2
13	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	No	Yes	CV/PI	Molluscs, crustaceans, fish, snakes, lizards	3.7 ± 0.2
14	Asian Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	No	Yes	PI/CV	Fish,snakes, lizards, crustaceans and molluscs	2.02 ± 0.18
IV	**Recurvirostridae**						
15	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	No	Yes	IN/CV	Insects, molluscs, crustaceans	4.2 ± 0.12
V	**Charadriidae**						
16	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Yes	Yes	IN/CV	Insects, molluscs	1.32 ± 0.07
VI	**Phalacrocoracidae**						
17	Indian Cormorant	*Phalacrocorax fuscicollis* (Stephens, 1826)	No	Yes	IN/CV	Insects, molluscs	0.74 ± 0.12
VII	**Alcedinidae**						
18	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	Yes	Yes	PI/IN	Fish, insects	5.5 ± 0.18
19	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	Yes	Yes	PI/CV	Fish, crustaceans, snails, small reptiles	5.56 ± 0.18
20	Pied Kingfisher	*Ceryle rudis insignis* (Hartert, 1910)	Yes	Yes	PI	Fish	5.42 ± 0.18
VIII	**Corvidae**						
21	House Crow	*Corvus splendens* (Vieillot, 1817)	Yes	Yes	OM	Fish, fruit, crustaceans, scavenger	1.9 ± 0.1
IX	**Motacillidae**						
22	Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	No	Yes	IN/CV	Insects, crustaceans and molluscs	5 ± 0.42
23	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	No	Yes	IN	Insects and other invertebrates	4.5 ± 0.18
X	**Scolopacidae**						
24	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	No	Yes	IN/CV	Crustaceans, invertebrates	3.82 ± 0.19
XI	**Accipitridae**						
25	Black Kite	*Milvus migrans* (Boddaert, 1783)	Yes	Yes	CV/PI/OM	Fish, leftovers of chicken	3.2 ± 0.2
26	Brahminy Kite	*Haliastur indus* (Boddaert, 1783)	Yes	Yes	CV/PI/OM	Fish, leftovers of offal	4.62 ± 0.18

Feeding guild: IN—Insectivore (small arthropods) | CV—Carnivore (large arthropods and vertebrates) | PI—Piscivore (fish) | OM—Omnivore (plant and /or animal and scavenging on dead animals) | GR—Granivore (grains and seeds). Bird species have been put under feeding guilds according to their predominant diet after Gray et al. (2006). Inferences based on average values of minimum 90% observations between 2014 and May 2023.

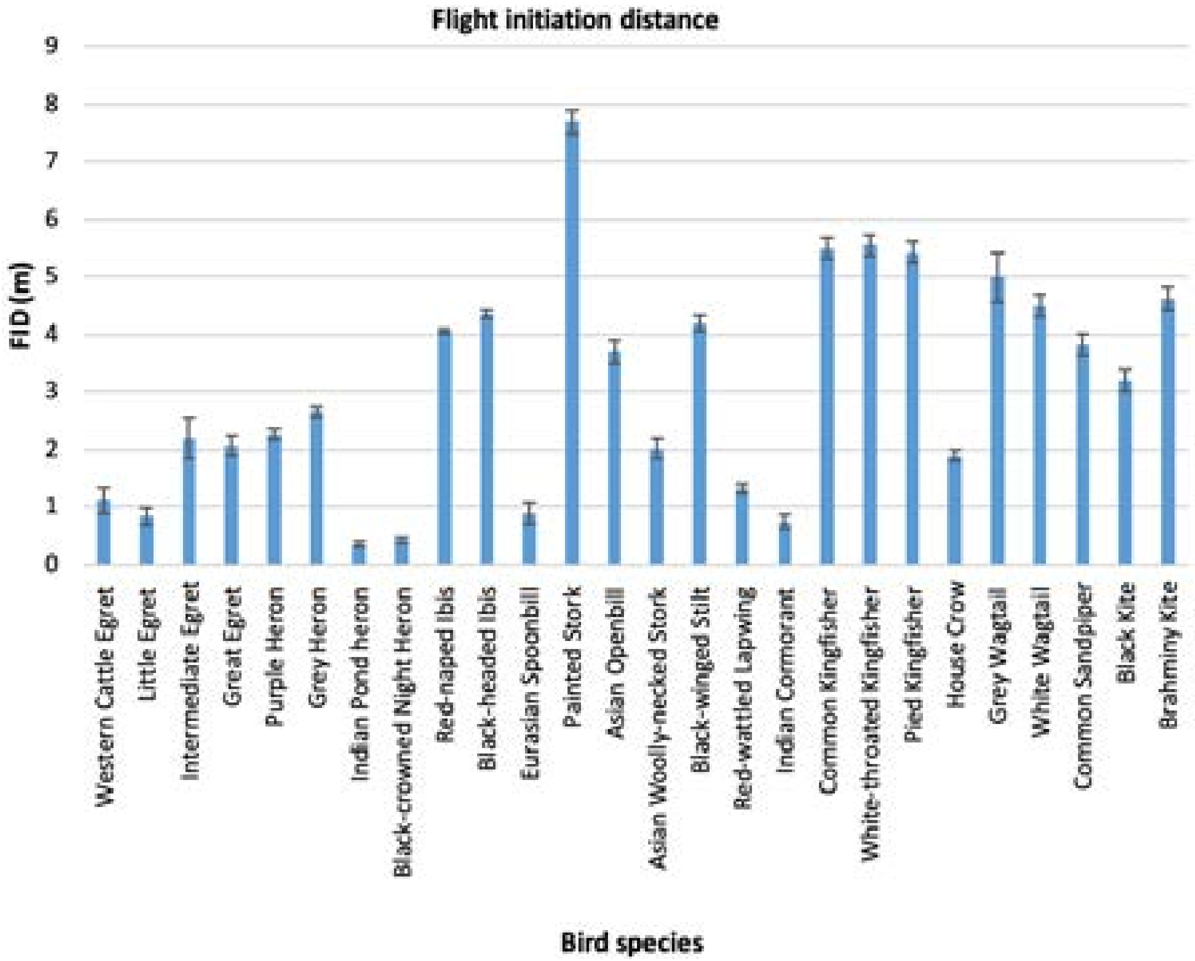

Figure 1. Flight initiation distance in meters (σ_M) of bird species that share crocodilian habitat in river Savitri, Mahad, Maharashtra.

OBSERVATIONS AND DISCUSSION

Foraging: Fishing and Hunting

At all the four stations we have been observing, Muggers of Savitri River were seen feeding on fish (80%) and birds (18%) of the times (Image 1). Bird prey species were egrets and herons predominantly. Also, on a few occasions they were seen scavenging on chicken offal thrown by the local poultry vendors. As this study was non-invasive, dietary composition could not be ascertained by analyzing stomach contents.

Muggers are generalist feeders whose diets comprise of a range of aquatic and terrestrial prey, juveniles mostly taking crustaceans, amphibians and fish; and adults going after larger vertebrates like fish, terrapins, tortoises, lizards, snakes, birds, monkeys, and dogs, besides carrion feeding (De Silva 2011, 2018; Chavan & Borkar 2022a). Research has shown that Muggers are opportunist predators that use available resources in and around the water in which they dwell, though fish stocks determine their success (Mobaraki 2015; Chavan & Borkar 2022a) and in India their food reportedly includes beetles, rats and frogs (Whitaker & Whitaker 1984).

Muggers fish and hunt, either individually or collectively; though hunting is done by a single individual, but if the prey is large then other Muggers are known to join in to share the meal (Dinets 2014).

Among vertebrates, though coordinated and collaborative hunting is reported in several mammals (Gazda et al. 2005), there are a few studies of such social behaviour in wild reptiles (Dinets 2017). Little is known about crocodilian hunting behaviours barring a few anecdotal observations (Dinets 2011; Doody et al. 2013). However, cooperative hunting is now known to occur in some crocodilian species (King et al. 1998; Dinets 2010) like the Nile Crocodile *Crocodylus niloticus*, Yacare Caiman *Caiman yacare*, Spectacled Caiman *Caiman crocodilus*, American Alligator *Alligator mississippiensis*, and Cuban Crocodile *Crocodylus rhombifer*.

The behaviour of cooperative hunting has not been well described except in a few cases (Dinets 2010). Cooperative hunting where more than two individuals partake has been reported in at least four crocodilian species, sometimes involving 'role partitioning' to optimize efforts (Mikloukho-Maklay 1892; Dinets 2010), though the prevalence of such behaviour appears to be highly underrated, and many observations remain unpublished (Doody et al. 2013).

The earliest evidence of role partitioning is in form of diary noting of Russian herpetologist Mikloukho-Maklay (1892) who observed cooperative fishing by Estuarine Crocodiles *Crocodylus porosus*. Similar collaborative fishing behaviour was reported in Australian Freshwater crocodile *Crocodylus johnstoni* from Australia, Spectacled Caiman *Caiman crocodilus* from Venezuela, Nile Crocodile *Crocodylus niloticus* from Botswana, and Mugger Crocodile *Crocodylus palustris* in Yala National Park, Sri Lanka (Dinets 2014).

Cooperative Fishing

In our study we have observed ritualized sequence of cooperative fishing, where mostly three Muggers (four partaking individuals only on one occasion) swim at a moderate but constant speed in circles (visually approximated to be of mean diameter 24.2m ± 1.7) and create a whirlpool in water, in which the fish remain congregated (Image 2) as inferred from the emergence of crocodiles from this vortex, with fish in their mouth; since the turbid waters did not permit direct observations of crocodile behaviour under submergence. The surface ripples and turbulence of water was seen to get intense as the Muggers submerged in water to feed. Collective fishing was observed nearly always during early morning hours from 0800 h to 0900 h, almost on a regular basis in Smashaan until the last observation in May 2023, and in the late afternoon hours at Kemburli up to the year 2018; these episodes being too regular to be treated as stray incidents. In their observations, King et al. (1998) and Dinets (2014) have focused on efforts that several crocodilian species put in towards cooperative

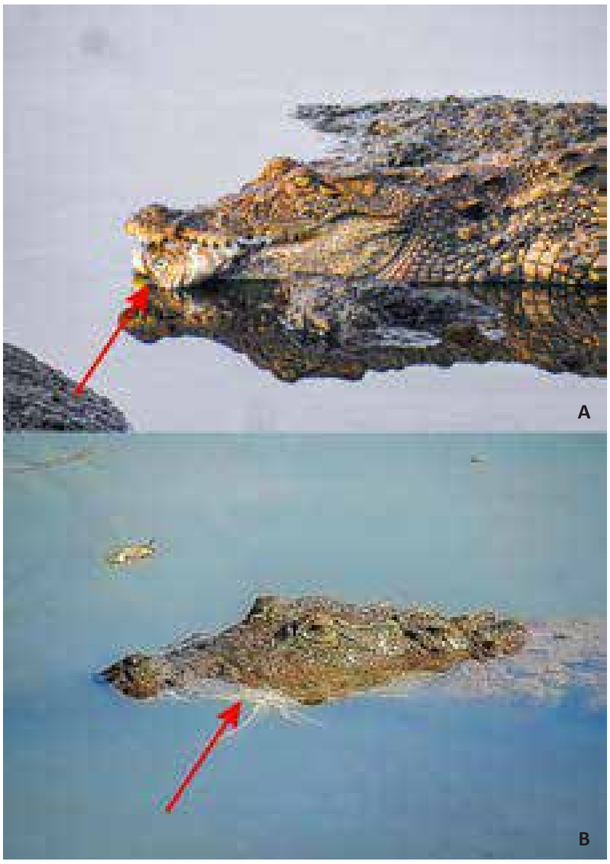

Image 1. Mugger *Crocodylus palustris* predominantly feeds on fish (A) but is also an ambush predator that takes birds as prey, as is the case with this Mugger(B) that has just successfully captured a Cattle Egret *Bubulcus ibis*. © Utkarsha Chavan & Sudhir Metkari.

Image 2. Cooperative fishing by Muggers in river Savitri, Mahad: A—three Muggers swimming in an equidistant circular formation | B—with whirlpools of ripples and turbulence. © Utkarsha Chavan.

strategies for optimal hunting. Cooperative fishing has been reported in American Alligators that demonstrate a stereotype sequence of circular swimming of more than two individuals with little vocalization, but intermittent jaw slapping to catch fish (Dinets 2010). These circular swimming episodes are different from those that are aimed at courtship and mating.

Dinets (2014) shares similar observations in Australian Freshwater Crocodiles, American Alligators and Nile Crocodiles. There are reports of Mugger feeding on Painted Stork flying close to water surface and chick of a Night Heron having fallen from its nest into the waters (Venugopal 2006), besides Teal (Battye 1945), Purple Moorhen, egrets and Common Coot (Vijaykumar et al. 1995). At our study site in Smashaan, Muggers calmly resting under the trees were observed ambushing Cattle Egrets sitting on the lower branches of trees.

Use of Bait for Hunting

Among the many facets of crocodilian behaviour, their use of baits to lure prey is an interesting premise of investigation. At Kemburli and Smashaan, Muggers were regularly seen lying still with short twigs on their snout, head, back, and even tail (Image 3). On one such occasion, it was observed that Cattle Egret came flying to pick up a stick, and the Mugger tried lunging at the bird; though the attempt was unsuccessful. Such deliberate trickery by placing twigs or rags (potential nesting material in bird roosting areas) seems strategic and deliberate, in that it can lure a nesting bird (potential prey) dangerously close and within striking distance of the Mugger. Prima fascia this behaviour hints strongly at the possibility of Mugger attempting to use a lure to attract the potential prey. It is interesting that such behaviour is increasingly witnessed during the nesting season of the common wading birds of this habitat. That crocodiles use tools for hunting has been meticulously established by Dinets et al. (2013), who report that the Muggers lay still in shallow waters with twigs positioned on their snouts to lure egrets that have rookeries around the crocodile occupied waters.

A few reports on the likely use of hunting baits or lures by crocodilians are anecdotal and lack robust empirical evidences (Shumaker et al. 2011). Dinets et al. (2013) has also recorded an unsuccessful attempt by a captive Mugger at MCBT Chennai in southern India to predate on an Intermediate Egret that got lured by a stick positioned on the Mugger's snout. However, he reports many individuals of crocodiles here that lay still balancing sticks, a potential nesting material for birds. It must also be noted that Dinets et al. (2013) have often seen Muggers emerging from water from underneath the floating sticks. Despite a discrete threat from the reptile that can capture the lured birds by deceit and swallow their fledglings fallen in water, there is a clear advantage for birds roosting on trees in water bodies; in that the very presence of the crocodiles serve as a deterrent for predators like Indian Rat Snake, Indian Rock Python, Indian Cobra, and rats that can scale a tree from beneath in search of bird eggs and fledglings.

It is rather common for these birds to compete for space and nesting material which they do not hesitate to pilfer from their competing neighbours. As such, shortage of nesting material may compel them to switch off their innate wariness towards the reptile with sticks on their body. In a crocodile occupied river like Savitri, it is interesting to understand how the birds invest in anti-predatory behaviour. Variously known as 'flight initiation distance' (FID), 'flush distance' (FD), and 'escape flight distance' (EFD); this important anti-predator behaviour has a species-specific consistency (Blumstein 2003, 2006). However, it is reasonable that individual experiences and perception of risk can influence FID between conspecifics and such a view has been corroborated by Bötsch et al. (2018).

Generally among the waders, species of Ardeidae had lesser FID. It is apparent that FID was lesser in the nesting season of birds indicating reduced wariness; making them vulnerable to crocodile ambushes while they get lured by nesting material. Such risk-taking decisions in nesting individuals have been reported (Dowling & Bonier 2018). 'Wariness' as used here refers to a 'level of fearful response' by the several bird species in response to potentially threatening presence of Crocodile manifesting in maintaining a 'safe distance' and flushing if that distance is violated (Images 4 & 5). Similar approach has been proposed earlier (Boissy 1995; Blumstein 2006).

Attraction towards marigold flowers

'Object play' has been frequently reported in captive crocodilians, and zoo keepers have often provided play objects as a part of zoo enrichment. However, Dinets (2015) submits that people observing such play behaviours do not consider these observations worth reporting and hence little is known about this curious behaviour. Various species of crocodiles are known to have been using floating debris in water as play-objects and show interest and attraction towards them. There are reports of captive Cuban Crocodiles and Western African Dwarf Crocodile *Osteolaemus* cf. *tetraspis* playing with pink Bougainvillea flowers over seven days

Image 3. Muggers of Savitri River use twigs as bait to lure nesting birds that forage as well as collect material for nidification from these shallow waters and basking zone. Note that the nesting material such as twigs and sticks are displayed prominently on snout (A, B & F), trunk (C, D & G), tail (D), and head (E). Also, the Mugger may position itself close to twigs within striking distances (H). © Utkarsha Chavan.

Image 4. Riverfront of Savitri offers congregation grounds for diverse bird species that wade and forage in the vicinity of Muggers. The bird species differ in their 'wariness' threshold, with some approaching the reptile dangerously close, while others keeping a safe distance. Egrets (A), Grey Heron (B) collecting twigs for nesting, Wooly-necked Stork (C), Black-headed Ibises (D & F), Back Kite (E), and Eurasian Spoonbill (F). © Utkarsha Chavan.

of observation, picking them up, pushing around, and carrying in the teeth or on the tip of the snout (Dinets 2015). Curiously, other coloured floating objects like the leaves, flowers and feathers were ignored. Also, many species are known to play with their prey carcasses. Of course, it is important to assess these behaviours against the criteria proposed by Burghardt (2005), before categorizing them as 'play'.

Though play behaviour of crocodiles was not the focus of this investigation, it was regularly observed that the Muggers in Smashaan region floated, basked, and lay in the vicinity of yellow or orange coloured Marigold flowers *Tagetes erecta* (Image 6). These marigold flower garlands end up in this stretch of the river from offerings to the corpses brought here for cremation. Unlike 'play object' value of Bougainvillea (Dinets 2015), the Muggers here were not observed manipulating these marigold flowers, but just lay in the vicinity of these

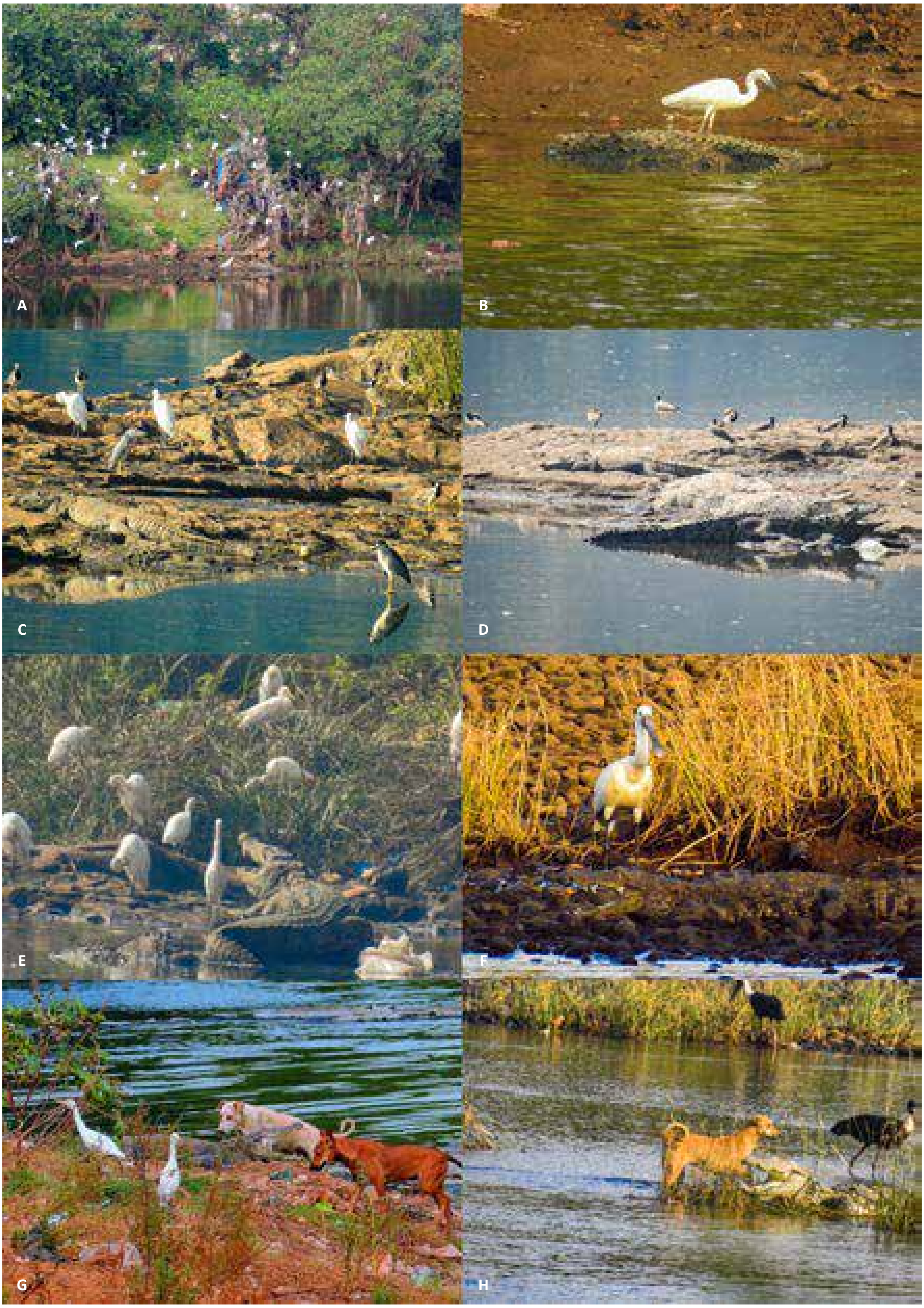

Image 5. Crocodiles under a rookery of egrets on the river bank (A), Median Egret (B & E), Median Egrets and Night Herons (C), Red-wattled Lapwings (D), Eurasian Spoonbill (F), Cattle Egrets and feral dogs (G), Wooly-necked Storks, and a dog (H) in the immediate proximity of crocodiles. © Utkarsha Chavan & Umesh Awadootha.

Image 6. The Mugger Crocodiles of Savitri were invariably found to be floating or basking in proximity of marigold flowers, suggesting their propensity towards these brightly coloured flowers. © Utkarsha Chavan.

floating flowers often with a physical contact. Though it has been conclusively established by Nagloo et al. (2016), that crocodiles have sophisticated colour vision; this behaviour is novel and intriguing, requiring further experimental enquiry and validation using established criteria for play behaviour (Burghardt 2005); both in captive Muggers and in situ.

It is noteworthy that petals of marigold are known to have antimicrobial compounds with potent bacteriostatic properties against dermal pathogens; including fungi, gram-positive and gram-negative bacteria (Padalia & Chanda 2015; Latifian et al 2021). Given that stretches of Savitri have been contaminated with sewage (Chavan & Borkar 2022a), the Muggers here are susceptible to a host of opportunistic pathogens. It is surmised that their contact with the Marigold flowers could alleviate much of their topical bacterial load.

Mugger Sentience

Animal sentience is understudied but an emerging area of research (Duncan 2006), and reptiles have received little attention (De Vere & Kuczaj 2016). Stray dogs were regularly seen to move amongst basking Muggers, without eliciting any hostility from the reptile (Image 5) suggesting reciprocal habituation. However, there were two incidences when these stray dogs were preyed upon by Muggers (Pers. comm. by residents staying near river).

On one occasion a young dog probably having strayed beyond its territory was chased by a pack of feral dogs after which the frightened individual inadvertently sought refuge by entering shallow water of the river Savitri. At this time three adult Muggers were clearly seen floating close by in the water and their attention was drawn to this dog and they moved closer towards the dog. What initially seemed to be a classical predatory instinct of the Mugger towards the hapless prey, soon turned out to be a more docile behaviour by two of the three crocodiles that guided the dog away from the site where it would have been vulnerable to

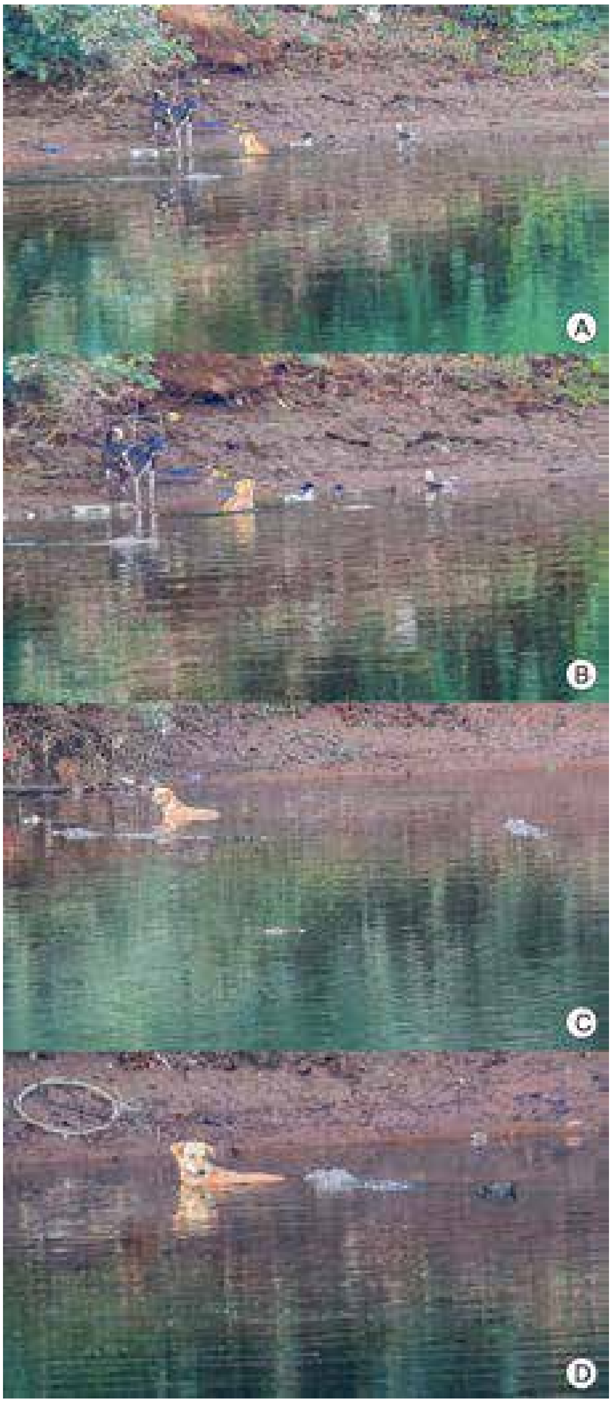

Image 7. Serial frames of a dog being given a 'safe passage' by three crocodiles, in a sentient behaviour suggestive of 'cross-species empathy'. © Utkarsha Chavan.

being attacked by the pack of feral dogs waiting on the river bank. These crocodiles were actually touching the dog with their snout and nudging it to move further for a safe ascent on the bank and eventually escape. The episode has been videographed and a few still frames have been presented here (Image 7). Reasons as to why the three crocodiles chose not to attack the potential prey remain speculative. Given that the mugger was well within the striking range and could have easily devoured the dog, yet none of them attacked and instead chose to nudge it towards the bank, implies that the hunger drive was absent; and we propose this to be a case of sentient behaviour of the Mugger resulting in cross species 'emotional empathy', which is not a very extensively investigated behaviour, though capacity of one species to experience the emotional feelings of another species merits recognition (Panksepp & Panksepp 2013). This underpins the need to validate assumed sentience of animals using exploratory and experimental approaches (Proctor et al. 2013).

CONCLUSION

Reptiles have been underestimated as far as animal cognition is concerned, perhaps due to a skewed impression that they are lethargic and at the most reflex machines (Jerison 1973) due to the small size and simple structure of their brain (Robin 1973). All in all, research in reptilian cognition hasn't progressed much due to such biases. Paradoxically some of the behaviour like 'tool use' previously believed to be a mammalian prerogative is now being reported from reptiles (Dinets et al. 2013; De Meester & Baeckens 2021).

Crocodilians (Crocodiles, Alligators, Caimans, and Gharials) are arguably the most cognitively complex living non-avian reptiles. They display a rich behavioural repertoire in a variety of contexts; such as hunting, spatial orientation, and social interactions, including communication in several modalities (Grendeus & Reber 2020). In so far as deliberate use of vegetation as camouflage or bait by crocodilians is concerned, Schumaker et al. (2011) reported the first case of *Crocodylus porosus* using fish fragments as a bait to attract bird prey. Dinets (2011) has recorded empirical evidence of higher frequencies of stick display behaviour among the alligators that occupy waters with rookeries during the nesting season of the birds. Thus, this was the first report of a reptilian predator not only using hunting bait, but also optimizing its use with the nesting behaviour of the bird prey. Opportunistic observations of *A. mississippiensis* and *C. palustris* with sticks on their snouts has been interpreted as tool use for luring nesting waders to ambushing distances has been reported (Dinets et al. 2013).

That in both these cases the crocodilian species were in the vicinity of wading bird rookeries and the birds did attempt to collect the sticks lend strength to the premise, that it was an attempt to improve hunting success. However, it is only through a study of controlled variables that more authentic evidence towards use of sticks as bait can be confirmed.

While use of flowers as 'play object' has been reported in captivity, this behaviour has not been firmly established in the wild. Hence play behaviour especially involving play objects such as flowers and other floating debris remains speculative, requiring detailed studies. Certainly, the water body under investigation where the crocodiles dwell receives a lot of vegetative material naturally and through human activity. Especially where the banks are used for cremation, a lot of flowers used in posthumous rituals end up floating in the river and remain there or get drifted until they decompose. Such conspicuous moving vegetative matter may elicit attack response from the crocodilians that may inadvertently end up ingesting it. Crocodiles are observed to have been attacking artificial objects that float or move passively on surface of water, particularly if these objects resemble large fruits (Somaweera et al. 2018).

Thus, it would be imprudent to draw a parallel between Dinets' observations (Dinets 2015) on Bougainvillea flower as play object of Cuban and West African Dwarf Crocodile and the propensity shown by Muggers of Savitri towards flowers of marigold. Perhaps more experimental evidence must be offered to propose such a behavioural analogy. However, given the antimicrobial property of marigold flowers, proximity to these flowers may offer some health benefits like bacteriostatic or bactericidal effects in a sewage contaminated environment.

The curious case of a dog 'rescued' by the group of crocodiles reported here seems more on lines of empathy than altruistic behaviour. However, there is little research done on such mental faculties of reptiles and this paper opens novel vistas of understanding behaviour of Muggers in general and that of Savitri River in particular.

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COMMUNICATION

Communal egg-laying by the Frontier Bow-fingered Gecko *Altiphylax stoliczkai* (Steindachner, 1867) in Ladakh, India

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Abstract: Communal egg-laying behaviour in the Frontier Bow-fingered Gecko *Altiphylax stoliczkai* was investigated within Ladakh's Indian trans Himalayan region during the summer of 2019. The findings present the first documented evidence of communal egg-laying in the species. Distinct egg-laying sites were identified with crevices containing between four and 10 eggs. Confirmation of species identity was achieved through post-hatching visual identification and genetic tests. Contrary to prevailing notions of one to two eggs per female gekkonid, the observation suggests that communal egg-laying involves multiple females. This behaviour attributes to the unique environmental challenges of high-altitude mountainous terrain, proposing significant reproductive benefits for the species.

Keywords: Adaptation, agama, Baltistan Gecko, behaviour, cold-desert, ectotherm, high-altitude specialist, mountain herpetofauna, oviposition, trans Himalaya.

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Author contributions: DP—carried out the fieldwork, analysed the data, wrote the paper, coordinated with co-authors, and edited the manuscript. CR—provided comments, inputs, and feedback on the manuscript. SG—provided comments, inputs, feedback on the manuscript, helped with the analysis, and edited the manuscript. PR—provided support and resources for fieldwork and provided feedback on the manuscript.

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INTRODUCTION

Animal aggregations have received considerable attention regarding their adaptive value (Hamilton 1971; Treisman 1975; Turner & Pitcher 1986; Inman & Krebs 1987). In comparison, aggregation for egg-laying has received relatively less attention (Danchin & Wagner 1997). Laying eggs with conspecifics is one of the oviposition strategies used by many reptilian species. This behaviour has been documented in many species including dinosaurs and, in contemporary times, about 481 species of reptiles and amphibians around the world (Plummer 1981; Graves & Duvall 1995; Brown & Shine 2005; Radder & Shine 2007; Doody et al. 2009).

The phenomenon of communal egg-laying, observed in various reptilian species globally, has prompted the formulation of several hypotheses to elucidate its drivers. These hypotheses include the notion that scarcity of optimal egg-laying sites with stable thermal and humidity conditions might influence this behaviour. However, none of these proposed hypotheses has achieved conclusive establishment as the definitive explanation. Despite multiple hypotheses aiming to explain the communal egg-laying behaviour in different species, consensus remains elusive, as underscored by the work of Doody et al. (2009).

Each species uses specific strategies for oviposition based on a combination of biological and environmental factors. Current literature has identified 'adaptation' and 'constraint' as two critical factors with high correlation with female lizards laying eggs with conspecifics. In this context, the term 'adaptation' refers to fitness benefits for young individuals and 'constraint' refers to the scarcity of favourable environmental conditions for laying eggs (Radder & Shine 2007). It is assumed that high-altitude cold deserts are one such place where environmental constraints have a significant influence on the ecology of various species, especially ectotherms/poikilotherms (cold-blooded) animals though this has been very poorly studied so far. Here, we elaborate on the egg-laying habits of one such high-altitude specialist reptile – the Frontier Bow-fingered Gecko *Altiphylax stoliczkai* in Ladakh, of the western Himalaya.

The Frontier Bow-fingered Gecko, also referred to as the Baltistan Gecko, belongs to the Gekkonidae family and thrives in high-altitude regions. Its global presence is confined to the Palearctic zones of northern India and Pakistan, specifically in central Asia and the trans Himalayan region within the *Altiphylax* genus, as highlighted in Bauer et al.'s (2013) work. In India, this gecko species is identified in the union territories of Ladakh and Jammu & Kashmir, formerly known as Jammu & Kashmir State, as documented by Smith (1935). The measurements align with Smith's (1935) data, indicating an average snout-to-vent length (SVL) and tail length (TL) of approximately 50 mm. Despite its presence, knowledge about the biology of *Altiphylax stoliczkai* remains limited. Displaying nocturnal behaviour, the species seeks shelter under small rocks for thermoregulation during daylight hours and is often found near human settlements. Although established as oviparous based on Auffenberg et al.'s (2004) work and Sharma's (2002) findings, there is a notable absence of documented proof or published records detailing its egg-laying strategy or preferred elevation range. This study contributes significant insights, presenting original observations from Ladakh, India, which provide the inaugural documented evidence of communal egg-laying behaviour exhibited by the Frontier Bow-fingered Gecko.

Study area

Ladakh (32.15–34.38 °N & 75.36–78.22 °E) is located in the rain shadow region to the north of the Himalayan ranges and the annual precipitation ranges 90–110 mm (Srivastava et al. 2009). The elevation in the region varies, ranging from an altitude of 2,600 m to over 7,000 m. The temperature ranges from an average of -30 °C in winter to 30 °C in the summer. The landscape in Ladakh is undulating, arid, and resource-scarce due to the lack of precipitation, short growing seasons and harsh, long winters. Ladakh is included in the trans Himalayan biogeographic region (Rodgers & Panwar 1998). Most of the region is treeless except for plantations, cultivated lands and areas along water sources (Kachroo et al. 1977; Hartmann 1983). The herpetological diversity and richness of Ladakh are similar to neighbouring regions of Gilgit-Baltistan (Ficetola et al. 2010) with which it shares geographical, topographic, and climatic characteristics. Currently, Ladakh has been documented to host four lizard species, one snake species, and one amphibian species (Patel et al. 2023).

MATERIALS AND METHODS

A series of comprehensive herpetological surveys were undertaken across diverse Ladakh habitats (Image 6) between March and September 2019. A cumulative 220 h were dedicated to surveying 150 km of randomised trails, averaging 6 km daily. The survey hours spanned 0800–1700 h. The primary objective centred on documenting reptile and amphibian diversity and abundance. Captured specimens underwent manual handling, with recorded metrics including snout-vent length (SVL) and total length (TL).

In this period, 61 randomly chosen sites were surveyed, each representing one of six distinct habitat types classified based on topography, ecology, and local insights. These encompassed riverine settings, rocky outcrops, plains of both sandy and rocky terrain, agricultural lands, sand dunes, and grasslands. Survey activities spanned both sunny and cloudy days, with limited nocturnal surveys due to logistical constraints.

RESULTS

During the survey, we obtained 119 sightings of *Altiphylax stoliczkai* in 24 of 61 sites in relatively dry areas. The observed individuals displayed morphological characteristics consistent with established literature. Specifically, this gecko species is medium-sized and often exhibits a shorter tail. Its body and head show slight dorso-ventral compression, with the dorsal surface featuring greyish colouring and dark brown wavy cross-bars, while the ventral surface appears greyish-white. The extent of tail swelling varies among individuals, being more prominent in recently regenerated tails.

In addition to morphometric measurements, a genetic analysis was performed on a tail segment collected from one of the sites, confirming the gecko species' identity. The corresponding genetic sequence has been submitted to the National Centre for Biotechnology Information (NCBI) with accession numbers MZ293046, MZ293045, MZ293047, and MZ293044.

Since the species is nocturnal, it was observed hiding under rocks during the day and foraging during the night (Image 1). The survey encompassed a sample size of 119 adult *A. stoliczkai* individuals, yielding mean snout-vent length (SVL) and tail length (TL) values of 51.27 ± 14.99 mm and 72.60 ± 34.65 mm, respectively.

During the survey in early August (1–10 August 2019), clusters of eggs were found at four sites (Table 1). These sites were located near the villages of Ney (six eggs), and Phyang (four eggs) in Leh District; and Chiktan (four eggs), and Wakha (10 eggs) in Kargil District, in the Union Territory of Ladakh. The egg measurements at the site in Ney ranged 11.7–12.87 mm in length and 8.84–9.91 in width. Eggs measurements at the site in Phyang ranged 12.3–12.88 mm in length and 9.89–9.93 mm in width whereas at the sites in Chiktan and Wakha, they ranged 12.41–12.86 mm in length, 9.93–9.94 mm width and 11.9–12.81 mm length, 8.85–9.88 width, respectively. No adult *Altiphylax stoliczkai* or hatching was observed near these egg-laying sites during multiple visits to the same sites. In Ney, Phyang, and Chiktan- the eggs were located beneath medium-sized boulders covered with loose soil. The Ney and Phyang sites were relatively flat with small to medium-sized boulders (Images 2 and 4). The site in Wakha was located on a steep south-facing mountain slope with rocky outcrops. Here, the soil was relatively compact and 10 eggs were observed through a narrow fissure in a rock (Images 3 and 5). On closer inspection, we found a broken egg. We were able to identify the premature neonate inside of the broken egg as *Altiphylax stoliczkai* by its physical features that match with literature descriptions. We cautiously measured, and photographed the eggs at all the sites to avoid embryo damage. Though this species has been recorded near human settlements, all the above-mentioned sites were at least three to four km from the nearest human habitation with minimal disturbance and no flowing water in the immediate vicinity. Since all survey sites were located away from human habitation, currently fewer data are available on egg-laying behaviour near human settlements. Common vegetation in these areas included Ephedra *Ephedra gerardiana* and wormwood *Artemisia* spp.

DISCUSSION

Upon the eggs' discovery, the identity of the species responsible was unequivocally determined only at the Wakha site, as previously mentioned. To establish the egg layer at the other three sites, we employed deductive reasoning and indirect indicators. Despite the presence of Theobald's Toad-headed Agama *Phrynocephalus theobaldi* Blyth, 1863 at the Ney and Phyang sites, the viviparous nature of this species ruled it out as the egg layer. Consequently, *Altiphylax stoliczkai* emerged as the likely candidate. Similarly, the Himalayan Agama *Paralaudakia himalayana* Steindachner, 1867 was observed at the Wakha and Chiktan sites It is oviparous but the eggs of agamas are leathery and ellipsoidal in shape making them distinctly different from the eggs of geckos. Also, most agamid species dig small burrows to lay their eggs. The ones we observed were spherical and hard-shelled (Table 1), which is typical of eggs laid by members of the Gekkonidae family (Andrews 2004). Further egg comparison among the three

Image 1. An adult Altiphylax stoliczkai from Ladakh, India.

Image 2. Rocky plain habitat.

Image 3. Rocky outcrop habitat in Ladakh.

Image 4. Broken egg shells covered with soil in rocky plain habitat.

sites and the confirmed Wakha identification showed notable consistency. Subsequent validation occurred by revisiting the sites at least twice after the initial discovery, culminating in hatching around mid-August and confirming *Altiphylax stoliczkai* as the egg layer.

A review of the current literature suggests that this is the first record of such an en masse, communal egg-laying strategy used by *Altiphylax stoliczkai.* Auffenberg et al. (2004) allude to the possibility that this species might be laying eggs communally based on observations of eggs near Skardo in Baltistan but did not provide any

Image 5. Egg clutches in rock fissure supported by old egg shells.

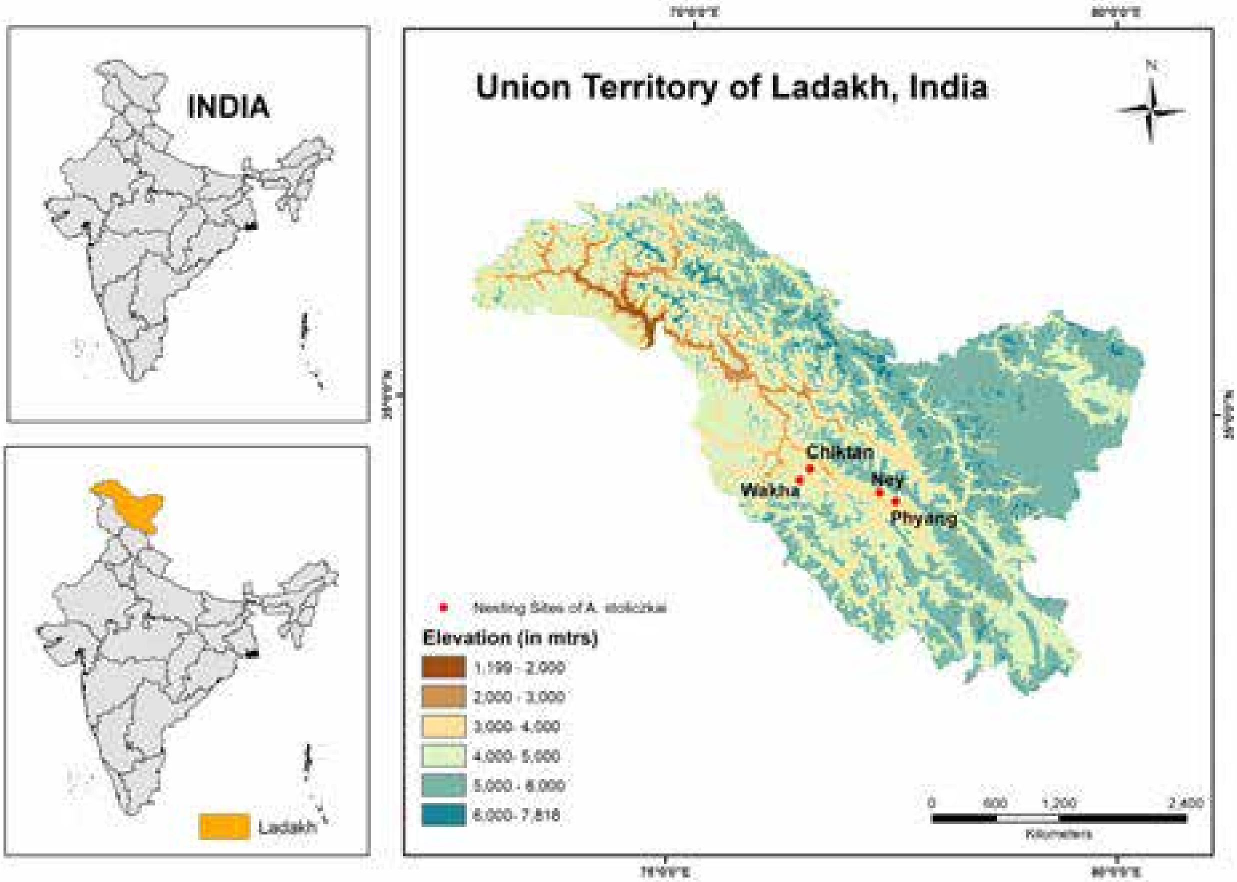

Image 6. A map of the study area.

Table 1. Details of eggs, egg-laying sites and other lizard species recorded in the habitat along with egg clutches of *Altiphylax stoliczkai* in Ladakh, India.

Site name, GPS, and elevation (m)	Habitat type	No. of eggs (n)	Range of egg measurements (mm)		Average size of eggs (mm)		Type of shell	Presence of old eggshells	Sympatric lizards and their reproductive strategies	
			Length	Width	Length	Width				
Wakha N 34.369381 E 76.382559 3396 m	Rocky outcrop	10	11.9–12.81	8.85–9.88	12.15	9.23	Spherical, hard	Yes	*P. himalayana*	Oviparous agamid
Chiktan N 34.4751306 E 76.4962916, 3337m	Rocky outcrop	04	12.41–12.86	9.93–9.94	12.63	9.94	Spherical, hard	Yes	*P. himalayana*	Oviparous agamid
Ney N 34.265275, E 77.295730 3575m	Rocky pains	06	11.7–12.87	8.84–9.91	12.16	9.23	Spherical, hard	Yes	*P. theobaldi*	Viviparous agamid
Phyang N 34.1838889, E 77.482666 3551 m	Rocky plains	04	12.3–12.88	9.89–9.93	12.59	9.91	Spherical, hard	Yes	*P. theobaldi*	Viviparous agamid

details or confirmation. The measurements of the three eggs collected by them ranged 9.7–11.1 mm in length and 7.6–8.5 mm in width which is smaller than the eggs we recorded. This difference is probably a reflection of body size as our largest recorded adult (SVL = 59.27 mm) was larger than the largest adult (SVL = 46.5 mm) reported from Baltistan. The species was documented within sites positioned at altitudes ranging 3,000–4,026 m, a higher elevation than the previously reported range of 2,300–3,700 m documented by Auffenberg et al. (2004).

Neither the process of egg-laying nor genetic tests to ascertain distinct female contributors per egg-laying site were observed or conducted. Nonetheless, it is noteworthy that the majority of gecko species tend to yield a maximum of one or two eggs during a given time frame (Shine & Greer 1991; Doughty 1996; Mesquita et al. 2016). Additionally, a relationship exists between the size of a gecko and its clutch size, with the former serving as a constraining factor on the number of eggs a female can produce (Doughty 1996).

Thus, communal egg-laying in geckos might be a behavioural adaptation to cope with the constraint of clutch size, as it increases female fitness by improving the performance of hatchlings (Blouin-Demers et al. 2004; Radder & Shine 2007). Current literature correlates this behaviour with social factors (Brown & Shine 2005; Radder & Shine 2007; Refsnider et al. 2010), scarcity of suitable egg-laying sites (Rand & Dugan 1983) and reduction of predation risk (Martin 1998; Spencer 2002). Of these, the scarcity of suitable egg-laying sites is the most commonly cited factor to explain communal egg-laying. In this regard, suitable sites provide desired thermal and humidity conditions. This is perhaps even more important for species that do not show post-egg-laying parental care, especially reptiles and turtles. While this could be one of several factors, it contributes to the adoption of communal egg-laying behaviour in certain species (Bustard 1968; Shine & Greer 1991; Doughty 1996; Doody et al. 2009).

Most oviparous lizards generally do not engage in parental care, and the success of their reproduction depends primarily on choosing optimal egg-laying sites (Pike et al. 2011). The scarcity of suitable egg-laying sites, as determined by optimum temperatures and moisture conditions are important factors that influence the success of the communal egg-laying strategy among reptiles and amphibians (Graves & Duvall 1995; Rand 1967). In addition, communal egg-laying provides many adaptive benefits including reduced predation risk. The larger the group of eggs, the smaller the probability of predation risk faced by each egg (Mateo & Cuadrado 2012). Furthermore, egg-laying sites located under large boulders are assumed to have stable conditions required for the incubation of eggs due to stable microclimatic processes (Garcia-Roa et al. 2015). Also, proximity with other eggs is known to alter moisture and thermal exchange to reduce water intake and produce healthier offspring (Radder & Shine 2007; Dees et al. 2020).

A substantial quantity of old and new eggshells was observed at all four egg-laying sites, implying their recurrent utilization. There were no egg-laying sites for this or any other species nearby. Adverse climatic conditions in the region might have incentivized individuals of this species to select previously successful sites. This not only increases the likelihood of success but also reduces the energy expenditure needed to locate new sites with unfamiliar microclimates (Doody et al. 2009). Mountain herpetofauna species, in particular, could be more susceptible to climate change impacts (Sinervo et al. 2010). Furthermore, limited optimal egg-laying sites, harsh weather conditions, and unpredictability could contribute to these adaptive strategies. Ladakh's demanding climate conditions create challenges for ectotherms/poikilotherms reliant on external heat sources and adaptive behaviours for temperature regulation. Extended periods of cold weather and intense solar radiation due to elevation make the region unsuitable for ectotherms. The existing species have developed energy-efficient strategies to meet nutritional needs and adjust to the environment, potentially explaining the region's diminished species diversity. While these reptilian species evolve physiological adaptations over time, behavioural adjustments are less resource-intensive and time-consuming (Hertz 1981). Communal oviposition might well represent one such adaptation.

The precise cues guiding individual geckos' selection of egg-laying sites and whether this decision-making occurs independently or collectively remain uncertain. An intriguing possibility is that geckos acquire familiarity with these sites through individual observation, potentially coupled with site-specific cues such as the presence of aged eggshells and optimal microclimatic conditions. However, a comprehensive investigation of these factors is essential for deeper comprehension. Additionally, as mentioned earlier, another oviparous species, the Himalayan Agama, was observed at two sites without the discovery of their nests. This observation suggests that *Altiphylax stoliczkai* and *Paralaudakia himalayana* likely do not engage in site competition due to distinct egg-laying strategies and site preferences, presumably influenced by inherent variations in egg size and clutch size.

Communal egg-laying behaviour has been observed in certain species where egg-laying sites are inherited across generations. This phenomenon, known as natal homing, has been documented in various species, including sea turtles and snakes (Meylan et al. 1990; Graves & Duvall 1995; Brown & Shine 2005;). For instance, in Morton National Park, located in south-eastern Australia, a mark-recapture study focusing on Lesueur's Velvet Gecko *Oedura lesueurii* revealed that hatchlings return to their natal nests as gravid females (Webb et al. 2008). A similar pattern was identified among Oudri's Fan-footed Gecko *Ptyodactylus oudrii* in northern Africa, where the presence of eggshells plays a pivotal role in selecting egg-laying sites (Mateo & Cuadrado 2012). Additionally, Pike et al.'s (2011) experimental study involving *Oedura lesueurii* showcased the geckos' reliance on both biotic (eggshell presence) and abiotic (thermal and moisture conditions) cues when choosing egg-laying sites. Interestingly, they showed a preference for sites with hatched eggshells and stable, cooler temperatures over warmer alternatives. Notably, these aspects remain unexplored in the context of *Altiphylax stoliczkai*, particularly regarding its biological requirements and the environmental constraints unique to the Ladakh region.

While these observations are significant, they also highlight the large knowledge gap that exists about the ecology of reptiles in cold regions such as Ladakh. The findings of this paper point to several lines of investigation to gain further insights into various strategies employed by ectotherms in response to various environmental challenges in Ladakh. The study findings will help design further long-term studies to understand various behavioural choices and this, in turn, will help develop appropriate conservation strategies for herpetofauna in Ladakh and regions with a similar climate.

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COMMUNICATION

Description of a new species of the genus *Anthaxia* (*Haplanthaxia* Reitter, 1911) from India with molecular barcoding and phylogenetic analysis

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Abstract: This paper deals with the description of a new *Anthaxia* (subgenus *Haplanthaxia* Reitter, 1911) species from southern India, which belongs to the *Anthaxia* (*H.) winkleri* Obenberger, 1914 species-group: *Anthaxia* (*H.*) *keralensis* **sp. nov.** In addition to a morphological description, we also generated mt. COI DNA sequences and discuss the results of a phylogenetic analysis of the new species with previously deposited COI DNA sequences of *Anthaxia* spp. In a maximum-likelihood phylogenetic analysis, the new species shared the same hypothetical ancestor node with *A. melancholica* Gory, 1841 and similar molecular characteristics (~48% similarity) with *A. tenella* Kiesenwetter, 1858 and *A. corinthia* Reiche & Saulcy, 1856. More systematic studies are required to understand the species diversity, distribution, biology, and evolutionary significance of the *Anthaxia* (H.) species groups.

Keywords: Beetle, Buprestidae, CO1 gene, Coleoptera, molecular phylogeny, oriental region, southern India, Western Ghats.

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Author details: Dr. Seena, S. completed her PhD from University of Calicut and the thesis dealt with the morphology, molecular, morphometric study of Jewel beetles of Kerala, South India with special emphasis on antennal sensilla structure and light reflection mechanisms of Buprestid. P. P. Anand doing Ph. D research (University of Calicut) on molecular aspects of mussel foot proteins. Dr. Y. Shibu Vardhanan working as associate professor in Zoology, University of Calicut. His lab focused diverse aspects such as geometric morphometrics, toxicology, Biochemistry, molecular biology, biomaterial characterization and waste management.

Author contributions: Field level collection: SS; Description: SS and PPA; molecular analysis: SS and PPA; Supervision: YSV.

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INTRODUCTION

Buprestidae is one of the world's largest coleopteran families, with nearly 15,000 extant species in 522 genera (Bellamy 2008). The genus *Anthaxia* Eschscholtz, 1829, is a diversified taxon with a wide distribution; this genus includes 697 species worldwide (Bellamy 2008; Kubáň 2016). The genus *Anthaxia* comprises eight subgenera (Bílý 2019), of which *Haplanthaxia* Reitter, 1911 is the largest, comprising 70% of species of the genus. There are currently 20 defined species-groups in the subgenus *Haplanthaxia* and many more awaiting definitions (Bílý 2017, 2019). Due to its worldwide distribution and the extreme morphological similarity of some species, it is considered as the taxonomically most challenging group in Buprestidae (Bílý 2019). Anthaxiini from the Oriental region, particularly from the Indian subcontinent, have received little attention. Southern Indian *Anthaxia* (*H*.) has not yet been studied; in this work, we discuss the new species from *Anthaxia* species group.

In addition to the morphological description, we discuss the molecular phylogenetic position of our new species among relative species. Due to limited sampling, the Buprestidae group's molecular identification, classification, and phylogenetic analysis are not yet well developed. At present, species identification and classification are primarily based on morphological characteristics. Compared to other buprestid genera, *Agrilus* Curtis, 1825, which has received the most attention in molecular barcoding and phylogenetic analysis. Kelnarova et al. (2018) investigated and developed the first DNA reference library for ~ 100 *Agrilus* species from the Northern Hemisphere using three mitochondrial markers: *cox1-5'* (DNA barcode fragments)*, cox1-3', and rmL.* Rapid detection and taxonomic identification of buprestid species is the first step, especially if the species is economically significant. Recently, mitochondrial DNA-based species identification methods have become increasingly important as a practical alternative to classical morphology-based identification (Herbert et al. 2003; Riedel et al. 2013a, b; Ashfaq & Herbert 2016). Here, we present the first molecular mt. CO1 barcoding sequence of the genus *Anthaxia* from India, with the first mt. CO1 phylogeny analysis of all known *Anthaxia* species available in NCBI and BOLD databases.

MATERIALS AND METHODS

Specimens studied here were collected with yellow pan traps from the Aralam wildlife sanctuary (11.9505^{0}N 75.8231^{0}E, 238 m) in Kannur district, southern Western Ghats, Kerala, India. Images were taken with a Carl Zeiss SteREO Discovery.V20 microscope with a 6MP CCD sensor camera 506 attached and processed with Adobe Photoshop CS8 to standardize background and remove artifacts formed during stacking. In addition, measurements of body parts of holotype specimen were taken with Carl Zeiss SteREO Discovery V20 inbuild software. The holotype and paratype are deposited in the Department of Zoology, University of Calicut (DZUC) and will be transferred to the National Collections of Zoological Survey of India, Western Ghat Regional Centre, Kozhikode, Kerala (ZSIK).

The body length was measured in the middle of the body following the elytral suture (the same for the pronotal and elytral length); width of the body was measured at the maximum body width (usually the maximum span between lateral pronotal margins or span between the outer margin of humeral callosities) (Bílý 2020). The terminology used to describe surface sculpture is based on Harris (1979).

DNA extraction, amplification, sequencing, and phylogenetic analysis

Genomic DNA was extracted from the thoracic leg using Nucleospin® Tissue Kit (Macherey-Nagel) following the manufacturer's instructions. The extracted DNA was subjected to PCR amplification. PCR was performed in a reaction mixture containing 6.25 µL master mix (PCR master mix: Phire Hot Start II PCR Master Mix, Thermofisher, Cat. No: F125S), 1.25 µL forward and reverse primer, 1 µL extracted DNA sample and 3.25 µL water. The total volume of the reaction mixture is 13 µL. For performing PCR mitochondrial cytochrome c oxidase subunit 1 (CO1) amplification, we used Lep primer (LepF1 5' ATTCAACCAATCATAAAGATATTGG 3' and LepR1 5' TAAACTTCTGGATGTCCAAAAAATCA 3') (Herbert et al. 2004; Wilson 2012). The thermal profiles of CO1 amplification were 5 min at 95^o C, 40 cycles of 10 sec at 94^o C, 1 min at 52^o C, and 45 sec at 72^o C, followed by a final extension of 10 min at 72^o C. The purified PCR products were sequenced at Rajiv Gandhi Centre for Biotechnology (RGCB), Thiruvananthapuram, Kerala, India, using the dideoxy chain termination method (Sanger & Coulson 1975). The forward and reverse strands were aligned using Clustal W in MEGA X to ensure the sequences were clear without any mismatches, frameshift regions, premature stop codons, etc.

The sequences were checked in the NCBI BLAST tool to find similar sequences in the NCBI database. All mt. CO1 DNA sequences of *Anthaxia* species were retrieved from NCBI and BOLD database and aligned in MEGA X, MUSCLE alignment method (Kumar et al. 2018), and the aligned sequences were used for phylogeny construction analysis. To find out the best model for phylogeny analysis, we performed maximum likelihood fits of 24 different nucleotide substitution models. Models with the lowest BIC scores (Bayesian information criterion) are considered to describe the substitution pattern the best. For each model, AICc value (Alkaline information criterion, corrected), Maximum likelihood value (*lnL*), and the number of parameters (including branch lengths) are also validated (Nei & Kumar 2000). A total of 30 nucleotide sequences (including new species CO1) were used for phylogenetic analysis. GTR+G+I (General Time Reversible model + Gamma Distributed with Invariants Sites) model is the best model for the phylogeny construction analysis of the genus *Anthaxia* (Parameters = 67; BIC = 10045.924; AICc = 9554.572; *lnL* = -4709.885).

Phylogenetic relationship of taxa was analysed by using maximum likelihood and neighbour-joining method. The evolutionary history was inferred using the maximum likelihood method and the General Time Reversible model (Nei & Kumar 2000). The bootstrap consensus tree inferred from 1,000 replicates (Felsenstein 1985) is taken to represent the evolutionary history of the taxa analysed (Felsenstein 1985). Branches corresponding to partitions reproduced in less than 50% of bootstrap replicates are collapsed. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1,000 replicates) are shown next to the branches (Felsenstein 1985). Initial tree(s) for the heuristic search were automatically obtained by applying neighbour-join and BioNJ algorithms to a matric of pairwise distances estimates using the maximum composite likelihood (MCL) approach, then selecting the topology with superior log likelihood value. A discrete Gama distribution was used to model evolutionary rate differences among sites (5 categories (+G, parameter = 0.2661)). The rate variation model allowed some sites to be evolutionarily invariable ([+*I*], 18.07% sites). This analysis involved 30 nucleotide sequences (including new species CO1). Codon positions included were $1^{st}+2^{nd}+3^{rd}$+Noncoding. All positions with less than 95% site coverage were eliminated, i.e., fewer than 5% alignment gaps, missing data, and ambiguous bases were allowed at any position (partial deletion option). There was a total of 384 positions in the final dataset. Evolutionary analyses were conducted in MEGA X (Kumar et al. 2018).

RESULTS

Anthaxia (*Haplanthaxia*) *winkleri* Obenberger, 1914 species group

Small to medium-sized species (4.0–6.0 mm). The head is wide, the forehead is flat, wide, the eyes projecting beyond head contour; upper lobe of eye more obtuse. On the broad vertex, the inner rims of the eyes are far apart, diverging towards vertex. Frons rather variable, from flat, slightly grooved in the middle, to widely depressed; frontal pubescence thicker, more sparse, rather reclined; clypeus almost flat. The forehead is always dark copper or green in colour, as is the rest of the body, only rarely a little lighter. The pronotum is almost twice as wide as long, fairly flat, depressed, the posterior angles not protruding backwards at all. It is widest in the anterior third, from there to the base and to the anterior margin finely and weakly, equally narrowed. Anterior margin deeply bisinuate, with pronounced central lobe. The posterior angles are rectangular. The structure of the pronotum is regular; it consists of low cells similar to those of the head; these are half extinct, very fine, only the central granules protrude somewhat more clearly, the walls of the cells are almost distinct. Scutellum slightly wider than long. The elytra are flat, without depressions, finely granulated, margins deep & wider, not shagreened, dark coppery, slightly wider in the shoulders than pronotum, individually tapered, and rounded at the apex. Metatibiae proportionally shorter, stronger, inner edge usually more strongly sinuate, incised, acutely serrate, with stronger, more acute apical spur. Aedeagus narrower, less sinuate; apex median lobe subparallel, more angulate, acutely pointed.

TAXONOMY

Anthaxia (*Haplanthaxia*) *keralensis* sp. nov.
(Image 1,2; Figure 1)

urn:lsid:zoobank.org:act:AF553762-19DC-438D-8BBA-8EE282C7130D

Material examined

Holotype: DZUC BLAK001, male, 10.vi.2019, Aralam Wildlife Sanctuary, Kerala, India, (11.9505^{0}N, 75.8231^{0}E, 238 m), coll: S. Seena".

Paratype: DZUC BLAK002, male, same as holotype.

Measurement (Holotype): total length 5.71 mm, the width of head 1.65 mm, length of pronotum 1.08 mm, the width of pronotum 1.89 mm, length of elytra 3.87 mm, and width of elytra 1.92 mm.

Diagnosis: Medium-sized (5.7 mm) (Image 2A), robust;

frons, vertex and pronotum bright green metallic with bronze lusters; elytra bronze with bright green lusters; ventral surface, antennae and legs bronze-green metallic, metepimera and abdominal ventrites green with bronze lusters; pronotum with distinct deep posterolateral depressions; lateral sides of 1st abdominal segment with tomentose spot; metatibiae straight, with dense hispid bristles externally; entire body covered with setose, golden yellow, small erect pubescence (Image 2).

Description of the holotype

Head slightly wider than anterior pronotal margin; frons convex, vertex weakly depressed, 0.5 times as wide as width of eye; frontoclypeus anteriorly slightly convex; eyes large, narrowly reniform, slightly projecting beyond the outline of the head; inner ocular margins parallel, feebly converging toward vertex; sculpture of head consisting of very small, dense, polygonal cells with central grains; short erect yellow pubescence uniformly distributed; clypeus roughly micro-sculptured (Image 2D); antennae long, almost reaching posterior pronotal angles when laid alongside; scape claviform, about 4 times as long as wide, pedicel suboval, about 1.5 times as long as wide; third antennomere triangular, about twice as long as wide, antennomeres 4–10 trapezoidal, slightly longer than wide, terminal antennomere rhomboid, twice as long as wide.

Pronotum weakly convex, 1.8 times as wide as long, with wide, distinct deep postero-lateral depressions; anterior margin bisinuate, posterior margin almost straight; lateral margins widely, regularly rounded, posterior angles obtuse-angled, maximum pronotal width at midlength; pronotal sculpture consisting of a simple, fine, network of subpolygonal cells with weakly raised borders, slightly denser on latero-posterior areas; cell bottom strongly micro-sculptured, with distinct central grain; bearing short, erect, golden yellow pronotal pubescence. Scutellum small, finely micro sculptured, pentagonal, as wide as long (Image 1A).

Elytra regularly convex and tapering posteriorly, 2.9 times as long as wide; basal, transverse depressions shallow, not reaching scutellum, humeral callosities small, only weakly projecting beyond elytral outline; elytral epipleura rather wide, parallel-sided, almost reaching elytral apex; lateral preapical serrations very fine, the apex of each elytron broadly rounded; elytral sculpture almost homogeneous, consisting of fine, dense, simple punctures with small erect golden pubescence; apex of elytra weakly dentate (Image 2A, 2C).

Ventral surface lustrous with finely ocellate sculpture, cell borders weakly raised; abdominal ventrites almost glabrous; prosternal process wide, subparallel, with well-developed and acute lateral angles; anal ventrite weakly truncate apically, slightly angulate and rather strongly serrate laterally (Image 2B). Legs long and slender, protibiae weakly curved, meso- and metatibiae straight, with dense hispid bristles externally (Image 2E); tarsal claws delicate, hook-shaped, not enlarged at base.

Aedeagus long, slender, weakly spindle-shaped, dorso-ventrally flattened, and the median lobe sharply

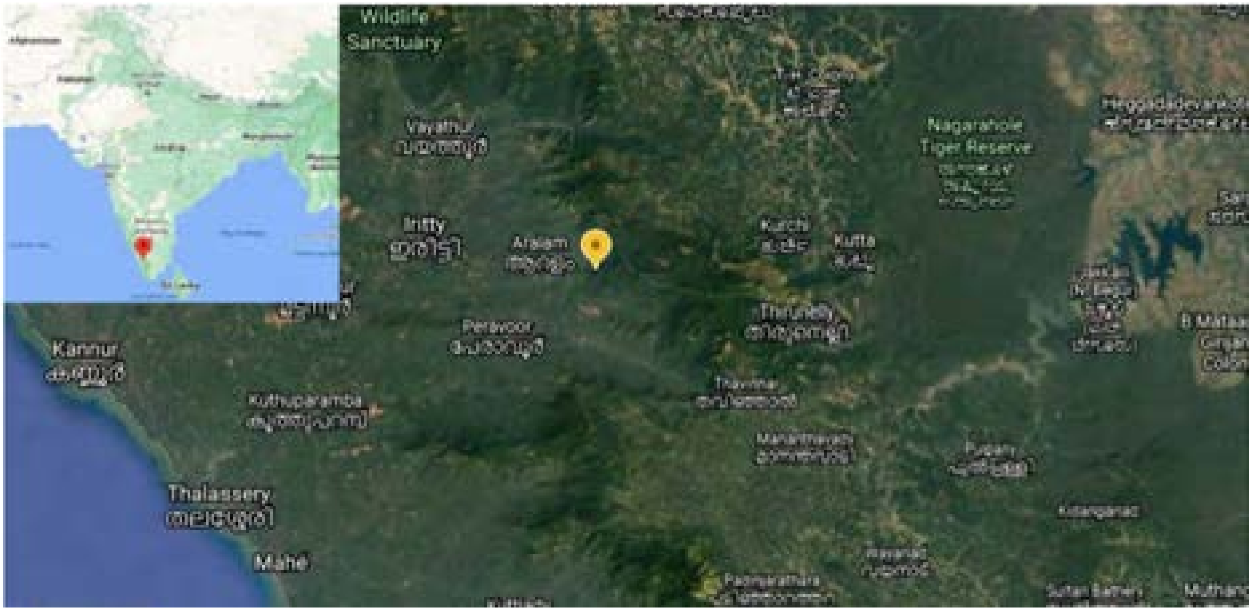

Image 1. Aralam Wildlife Sanctuary with Holotype collection locality (yellow mark).

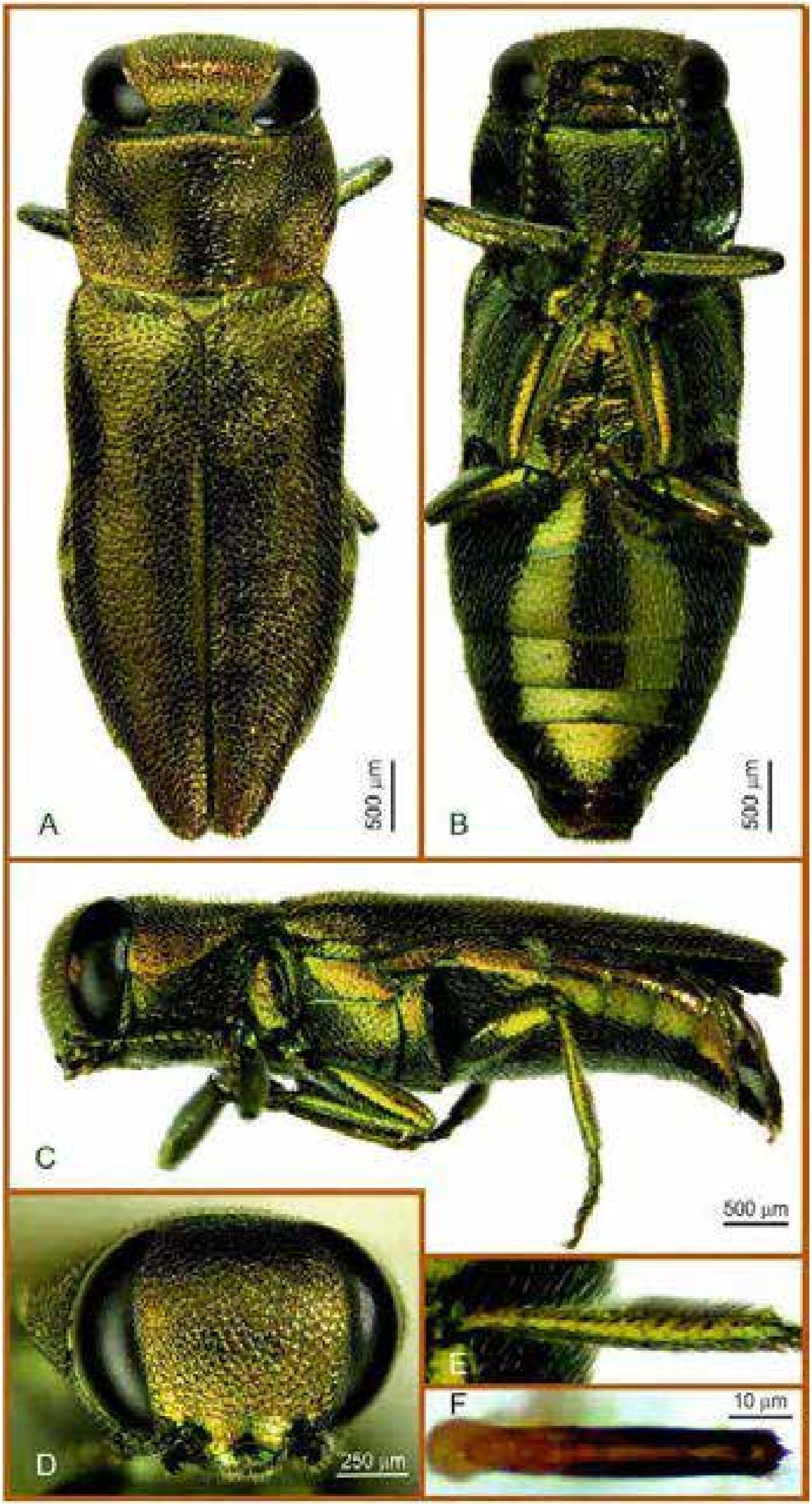

Image 2. ***Anthaxia*** **(*Haplanthaxia*)** ***keralensis*** **sp. nov. holotype DZUC BLAK001 (male): A—dorsal aspect | B—ventral aspect | C—lateral view | D—frontal aspect of head | E—Metatibia | F—Aedeagus. © Y. Shibu Vardhanan.**

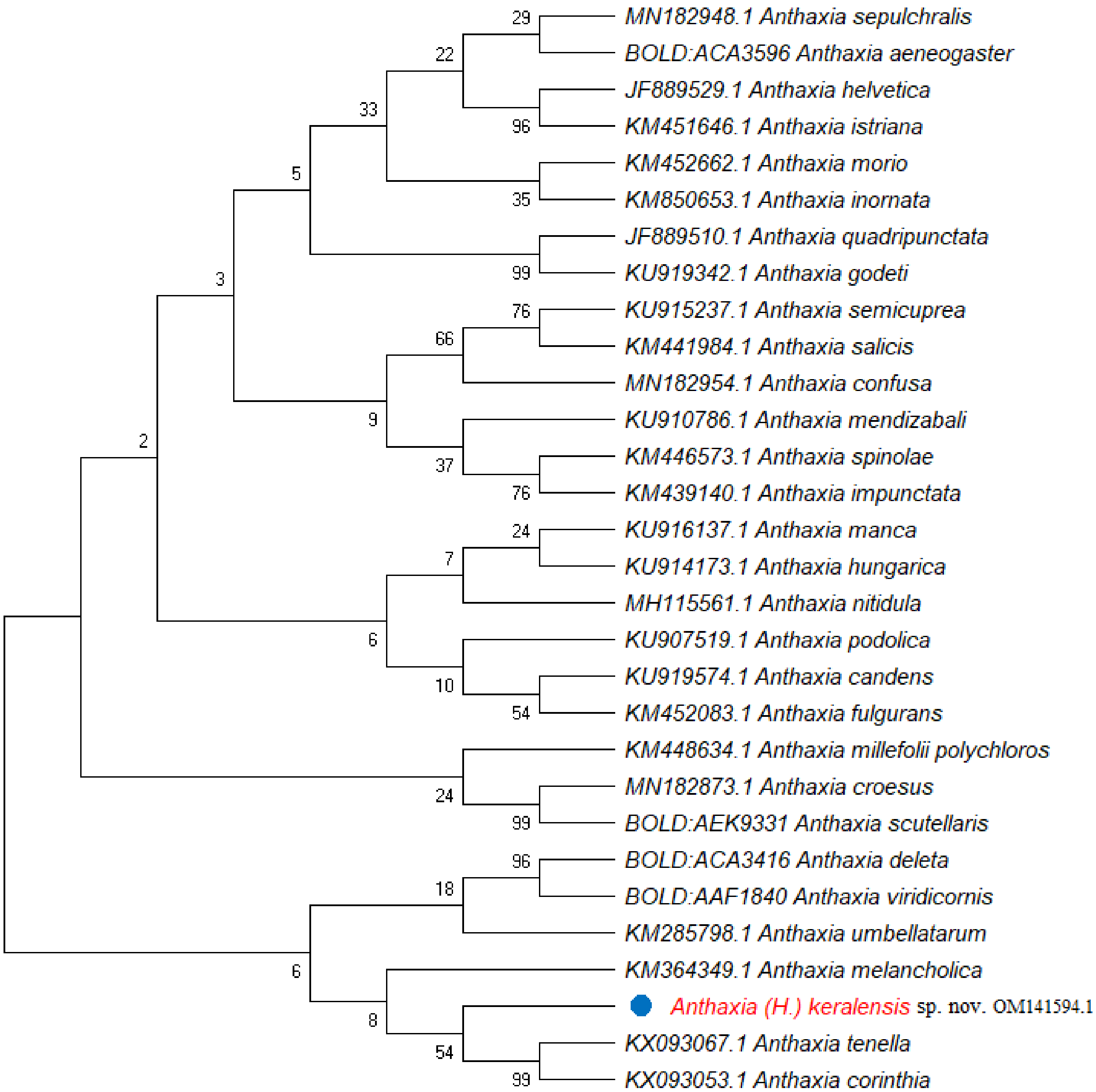

Figure 1. Maximum-likelihood phylogeny analysis. Red color indicated new species *Anthaxia* (*Haplanthaxia*) *keralensis* sp. nov. MUSCLE alignment, 1,000 bootstrap, developed in MEGA X.

pointed apically (Image 2F).

Female: unknown.

Etymology: The new species is named after the Indian state Kerala where the holotype was collected.

Distribution: India, Kerala State, known only from the type locality.

Differential diagnosis: This species is similar to *A. marshalli* Stebbing, 1914 and *A.* (*H.*) *tanjorensis* Obenberger, 1938 by size and general habitus but it distinguishes by its setose body, uniformly distributed golden yellow short erect pubescence, tomentum on the lateral side of 1st ventrite (Image 2C), and aedeagus shape (Image 2F). *A.* (*H.*) *keralensis* sp. nov. is easily distinguished from *A.* (*H.*) *tanjorensis* Obenberger, 1938 by its pronotonal sculpture, since *A.* (*H.*) *keralensis* sp. nov. has a pronotal sculpture usually regularly polygonal on the whole pronotal surface, but in longitudinally stretched on discal area as in *A.* (*H.*) *tanjorensis.*

Molecular phylogeny analysis

A total of 29 mt.CO1 barcoding sequences of the genus *Anthaxia* available in NCBI and BOLD database.

In the ML phylogenetic analysis (Figure 1), the tree divides into two major clades, one clade containing seven species and the other clade containing 23 species. *Anthaxia (H.) keralensis* sp. nov. (OM141594.1) is positioned in a distinct clade. *A.* (*H.*) *keralensis* sp. nov. and *A. melancholica* diverged from the same hypothetical ancestor node. *A.* (*H.*) *keralensis* sp. nov. showed a molecular relationship (~48% of similarity) with *A. melancholica, A. tenella,* and *A. corinthia.* The resulted molecular phylogeny of *Anthaxia* has a strongly preliminary character because all main clades and subclades have very low nodal support. Basal clade which includes new species, is formed by representatives of the subgenera *Haplanthaxia* (*A. deleta* [= *A. caseyi*] - *A. melancholica*) and *Melanthaxia* (*A. tenella* and *A. corinthia*). In the same time all other species of subgenus *Melanthaxia* form a monophyletic most distant subclade (*A. sepulchralis* - *A. godeti*). Intermediate subclades are also mainly polyphyletic and include representatives of subgenera *Anthaxia* s. str., *Haplanthaxia* and *Cratomerus*. Only basal subclade of the second clade comprises species of *Haplanthaxia.* It's important to remember that one of the factors contributing to the preliminary uncorrelated relationship of some *Anthaxia* spp. was a lack of data in genebanks. For the purpose of studying the molecular phylogenetic link among the *Anthaxia*, multilocus-based gene barcoding and the development of phylogenies with extremely comparable taxa will be helpful. More molecular and morphological systematic studies are required to understand the phylogenetic relationship among the *Anthaxia* spp.

CONCLUSION

The lack of proper revision of species from the Indian subcontinent and the high degree of morphological variability in the *A. winkleri* species group are significant impediments in assigning and describing a new species from India. The lack of appropriate molecular barcode sequences in GenBank databases makes mt. CO1 barcoding ineffective for species identification at the moment. Nevertheless, we can use the barcode for molecular phylogeny and genetic similarity analysis. *A. (H.) keralensis* sp. nov. showed no close similarity with previously studied *Anthaxia* spp. A multiple gene sequencing studies are required to confirm the species group belonging of newly described species and to build the molecular phylogeny and their evolutionary origin of the genus *Anthaxia*.

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COMMUNICATION

Odonata diversity in the Egra and its adjoining blocks of Purba Medinipur District, West Bengal, India

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Abstract: The research was carried out over a three-year period, spanning from March 2020 to March 2023, with the aim of examining the status and diversity of Odonata fauna across a range of natural and anthropogenic habitats situated in Egra, Purba Medinipur District, located in the state of West Bengal. In total, 42 odonata species from 31 genera and seven families were identified throughout the study period from the study region. There were 28 (67%) species in the suborder Anisoptera, belonging to four distinct families. On the other hand, 14 (33%) species in the Suborder Zygoptera, divided into three different families. The four families of suborder Anisoptera were Aeshnidae (10%), Gomphidae (2%), Libellulidae (53%), and Macromiidae (2%). In the suborder Zygoptera, three families were identified, namely Coenagrionidae (24%), Lestidae (2%), and Platycnemididae (7%). %). According to the relative estimate of abundance, 38% of the species were classified as not rare (NR), 31% very common (VC), 14% common (C), 14% rare (R), and 3% as very rare (R). In addition, the IUCN red data list indicates that 41 species have been classified as Least Concern (LC), while a solitary species has been categorised as Data Deficient (DD). The identification of Odonata is a critical factor in determining the ecological well-being of an ecosystem.

Keywords: Anisoptera, checklist, damselflies, dragonflies, habitat, taxonomy, Zygoptera.

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Author contributions: TS—data collection, research designing, data analysis and manuscript writing. AG—field work, data collection, photographic documentation & manuscript writing. LC—project planning, overall supervision. ABR—project planning, manuscript writing, interpretation & overall supervision.

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INTRODUCTION

Odonates (dragonflies and damselflies) are frequently used as global indicators of wetland health (Chovanec & Waringer 2001). They first made their appearance during the Carboniferous era, about 250 million years ago (Nair 2011). Odonata, a common group of insects found in freshwater habitats, have a life cycle that includes an extended larval stage in aquatic environments followed by a comparatively brief adult stage on land (Tiple et al. 2012). According to Clausnitzer et al. (2009), the larvae exhibit sensitivity towards the quality of water and the morphology of aquatic habitats, including the structure of bottom substrate and aquatic vegetation. Odonata was found to be effective biological control agents for agricultural pests, blood-sucking flies, and vector-borne diseases such as mosquitoes. Furthermore, they are useful indicators of environmental changes and the overall health of ecosystems (Nair 2011; Tiple & Koparde 2015; Mangaoang & Mohagan 2016). The worldwide population of odonates comprises 6,356 species across 693 genera. Throughout the Indian Subcontinent (Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka), a total of 588 species of odonates were recorded (Kalkman et al. 2020); similarly, 498 species consisting 154 genera and 18 families were recorded from India (Subramanian & Babu 2020). To date, Dawn (2021) has reported the existence of 239 species from 114 genera and 17 families in West Bengal. The current state of knowledge regarding the Odonata of southern West Bengal has been documented by various researchers, including Selys (1891), Fraser (1933, 1934, 1936), Ram et al. (1982), Srivastava & Das (1987), Prasad & Ghosh (1988), Mitra (1983, 2002), Srivastava & Sinha (1993), Gupta et al. (1995), Ghosh (2022), and Samanta et al. (2022). Studies on the diversity of Odonata in Purba Medinipur district have been conducted by various researchers including Prasad & Ghosh (1988), Jana et al. (2014) and Pahari et al. (2019). The extant literature on the diversity of odonata in Purba Medinipur district is limited. Prasad & Ghosh (1988) conducted the initial study in the estuarine regions of East India, specifically in West Bengal and Orissa. The survey locations included Balisai, Contai, Digha, Fatehpur (Nandakumar), Junput, Mahishadal, Nimalakhya, Nandakumar, and New Digha within the district. The survey documented a total of 22 species of odonates, classified into 19 genera and six families. Later Jana et al. (2014), reported 13 species of odonates belonging 12 genera and three families from eight contrasting coastal areas of the district. The extent of research conducted on the diversity of Odonata in Egra, located in Purba Medinipur, is currently limited. The current study was carried out within this geographical region with the goal of cataloguing the variety and proportional prevalence of odonates. The resulting inventory will be used to educate local people about the ecological importance of these organisms in this area.

MATERIALS AND METHODS

Study Area

The Egra subdivision encompasses the Egra municipality and five community development blocks, namely Bhagawanpur I, Egra I, Egra II, Pataspur I, and

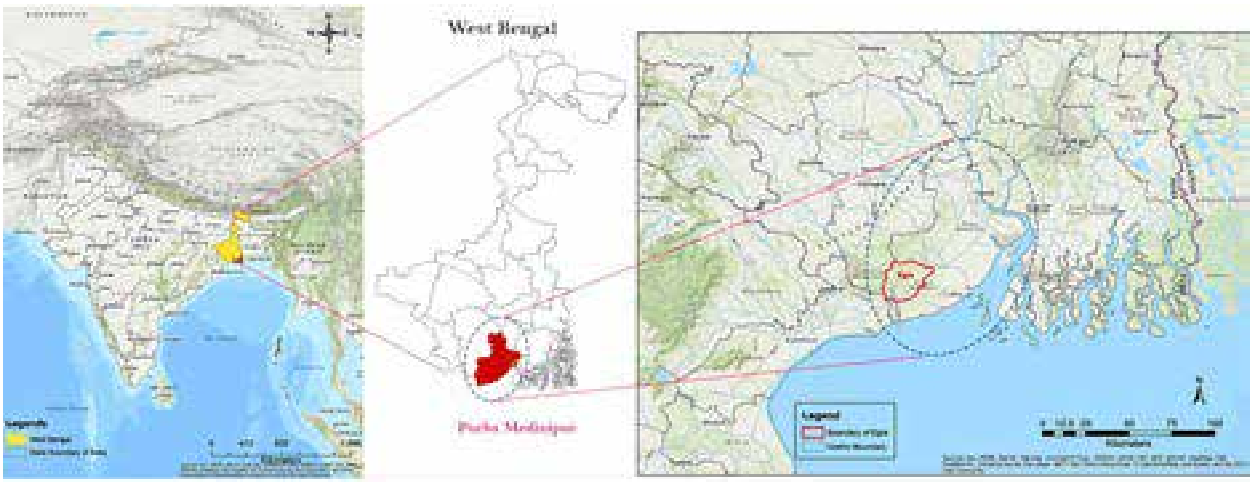

Figure 1. The map presented depicts the study area, with the yellow hue demarcating the boundary of West Bengal state , and the red hue indicating the boundary of Purba Medinipur District on the left. The eastern boundary of Egra within the district of Purba Medinipur is demarcated by a red border.

Pataspur II. But the focus was Egra municipality and Egra I and Egra II blocks. The aggregate land area of the three locations is 431.5 km^2, as depicted in Figure 1. These locations are located in the southern and south-western regions of West Bengal's Purba Medinipur District. Egra is located at 21.9°N, 87.53°E. The study areas primarily consist of extensive agricultural fields with limited clusters of trees and shrubs, as well as a few small forested regions, private gardens, village woodlands, and bamboo thickets, in addition to roadsides, ponds, and water channels (Samanta et al. 2022). The summer season (March–June) in this area experiences a temperature range of 30°C–38°C, while the winter season (November–February) has a temperature range of 15°C–25°C. The average annual rainfall in this district is around 1,700 mm (Payra et al. 2017).

Data Collection

The investigation was conducted over a period spanning from March 2020 to March 2023. The study employed the direct search technique as well as opportunistic sighting methods to gather data on the diversity and abundance of Odonata, as outlined by Sutherland (1996). The study involved biweekly site visits to various habitats (including ponds, canals, agricultural fields, gardens, and shaded areas within forest patches) to observe odonates. The photographs were taken using Nikon Coolpix P600, Nikon Coolpix B700 (Resolution: 20MP, Zoom: 60x) and a smartphone camera. Here, we have followed the systematic arrangement of the odonates proposed by Kalkman et al. (2020). The species were identified with the help of few guide books (Andrew et al. 2008; Nair 2011; Dawn & Roy 2016) and the unidentified species were identified with the help of expert guidance and the Citizen Science forum (iNaturalist, Odonata of India). Tiple et al. (2013) classified the odonates into five distinct groups based on their observed frequency in the area. These groups were denoted by the following abbreviations: VC—Very Common (> 100 sightings), C—Common (50-100 sightings), NR—Not Rare (15-50 sightings), R—Rare (2-15 sightings), VR—Very Rare (< 2 sightings).

RESULTS

The study area yielded a total of 42 species of Odonata, which were classified into 31 genera and seven families, as represented in Table 1. The data reveals that out of the total number of species observed, 67% (28 species) belonged to the sub-order Anisoptera, commonly known as dragonflies, while the remaining 33% (14 species) were classified under the sub-order Zygoptera, commonly known as damselflies (Figure 3). The sub-order Anisoptera encompassed four families, namely Aeshnidae (10%), Gomphidae (2%), Libellulidae (53%), and Macromiidae (2%). Meanwhile, the sub-order Zygoptera, encompassed three families, namely Coenagrionidae (24%), Lestidae (2%), and Platycnemididae (7%). The study area revealed that the Libellulidae family, which belongs to the sub-order Anisoptera, constituted the highest percentage (53%) of the species present. Following closely behind, the Coenagrionidae family of the sub-order Zygoptera accounted for 24% of the species present, as depicted in Figure 2.

According to our documentation (Figure 4, Image 1–42), among the 42 observed species, 38% were categorized under Not Rare (NR), 31% Very Common

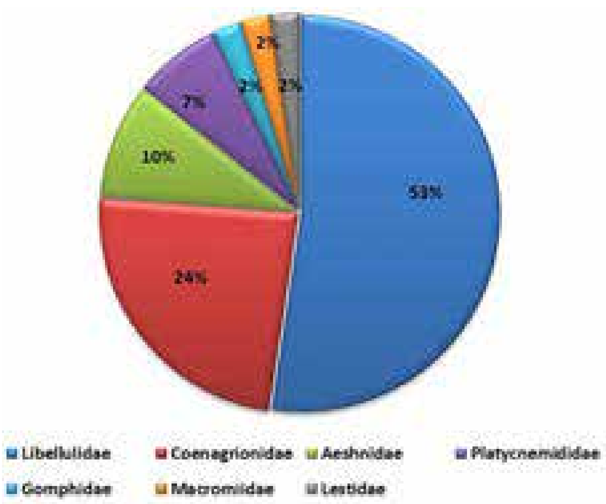

Figure 2. Abundance of different families

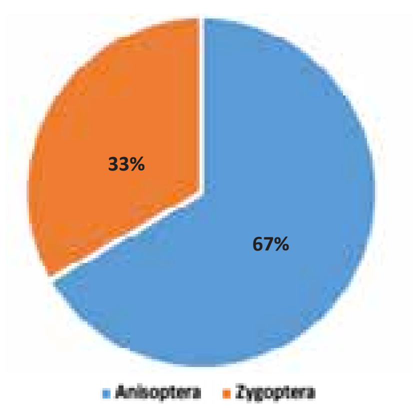

Figure 3. Relative abundance of Suborder Anisoptera and Zygoptera

Table 1. Checklist of Odonates recorded from the study area.

	Scientific name	Authority	Status	IUCN status
	Order: Odonata	Fabricius, 1793		
	Suborder: Zygoptera	(Selys, 1854)		
	Superfamily: Lestoidea	Calvert, 1901		
	Family- Lestidae	(Calvert, 1901)		
	Lestes	Leach, 1815		
1	*Lestes viridulus*	Rambur, 1842	VR	LC
	Superfamily: Coenagrionidea	Kirby, 1890		
	Family- Platycnemididae	(Yakobson & Bainchi, 1905)		
	Pseudocopera	Fraser, 1922		
2	*Pseudocopera ciliata*	(Selys, 1863)	C	LC
	Copera	Kirby, 1890		
3	*Copera marginipes*	(Rambur, 1842)	C	LC
	Onychargia	Selys, 1865		
4	*Onychargia atrocyana*	(Selys, 1865)	NR	LC
	Family- Coenagrionidae	(Kirby, 1890)		
	Agriocnemis	Selys, 1877		
5	*Agriocnemis kalinga*	(Nair & Subramanian 2014)	R	LC
6	*Agriocnemis lacteola*	Selys, 1877	NR	LC
7	*Agriocnemis pygmaea*	(Rambur, 1842)	VC	LC
	Ceriagrion	Selys, 1876		
8	*Ceriagrion cerinorubellum*	(Brauer, 1865)	VC	LC
9	*Ceriagrion coromandelianum*	(Fabricius, 1798)	VC	LC
	Ischnura	Charpentier, 1840		
10	*Ischnura rubilio*	(Selys, 1876)	NR	LC
11	*Ischnura senegalensis*	(Rambur, 1842)	NR	LC
	Mortonagrion	Fraser, 1920		
12	*Mortonagrion aborense*	(Laidlaw, 1914)	NR	LC
	Pseudagrion	Selys, 1876		
13	*Pseudagrion microcephalum*	(Rambur, 1842)	NR	LC
14	*Pseudagrion rubriceps*	(Selys, 1876)	NR	LC
	Suborder: Anisoptera	(Selys, 1854)		
	Superfamily: Aeshnoidea	Leach, 1815		
	Family- Aeshnidae	(Leach, 1815)		
	Anaciaeschna	Selys, 1878		
15	*Anaciaeschna jaspidea*	(Burmeister, 1839)	R	LC
	Anax	Leach, 1815		
16	*Anax guttatus*	(Burmeister, 1839)	NR	LC
17	*Anax indicus*	Lieftinck, 1942	R	LC
	Gynacantha	Rambur, 1842		
18	*Gynacantha dravida*	Lieftinck, 1960	NR	DD
	Superfamily: Gomphoidea	Rambur, 1842		
	Family- Gomphidae	(Rambur, 1842)		
	Ictinogomphus	Cowley, 1934		
19	*Ictinogomphus rapax*	(Rambur, 1842)	C	LC
	Superfamily: Libelluloidea	Leach, 1815		
	Family-Macromiidae	(Needham, 1903)		
	Epophthalmia	Burmeister, 1839		
20	*Epophthalmia vittata*	Burmeister, 1839	R	LC
	Family- Libellulidae	(Leach, 1815)		
	Acisoma	Rambur, 1842		
21	*Acisoma panorpoides*	(Rambur, 1842)	NR	LC
	Aethriamanta	Kirby, 1889		
22	*Aethriamanta brevipennis*	(Rambur, 1842)	NR	LC
	Brachydiplax	Brauer, 1868		
23	*Brachydiplax chalybea*	(Brauer, 1868)	NR	LC
24	*Brachydiplax farinosa*	(Krüger, 1902)	VC	LC
25	*Brachydiplax sobrina*	(Rambur, 1842)	VC	LC
	Brachythemis	Brauer, 1868		
26	*Brachythemis contaminata*	(Fabricius,1793)	VC	LC
	Crocothemis	Brauer, 1868		
27	*Crocothemis servilia*	(Drury, 1770)	VC	LC
	Diplacodes	Kirby, 1889		
28	*Diplacodes trivialis*	(Rambur, 1842)	VC	LC
	Neurothemis	Brauer, 1867		
29	*Neurothemis fulvia*	(Drury, 1773)	NR	LC
30	*Neurothemis tullia*	(Drury, 1773)	C	LC
	Orthetrum	Newman, 1833		
31	*Orthetrum pruinosum*	(Burmeister, 1839)	R	LC
32	*Orthetrum sabina*	(Drury, 1773)		LC
	Pantala	Hagen, 1861	VC	
33	*Pantala flavescens*	(Fabricius, 1798)	VC	LC
	Potamarcha	Karsch, 1890		
34	*Potamarcha congener*	(Rambur, 1842)	VC	LC
	Rhodothemis	Ris, 1909		
35	*Rhodothemis rufa*	(Rambur, 1842)	VC	LC
	Rhyothemis	Hagen, 1867		
36	*Rhyothemis variegata*	(Linnaeus, 1763)	VC	LC
	Tholymis	Hagen, 1867		
37	*Tholymis tillarga*	(Fabricius, 1798)	C	LC
	Tramea	Hagen, 1861		
38	*Tramea basilaris*	(Palisot de Beauvois, 1805)	R	LC
39	*Tramea limbata*	(Desjardins, 1832)	NR	LC
	Trithemis	Brauer, 1868		
40	*Trithemis pallidinervis*	(Kirby, 1889)	NR	LC
	Urothemis	Brauer, 1868		
41	*Urothemis signata*	(Rambur, 1842)	C	LC
	Zyxomma	Rambur, 1842		
42	*Zyxomma petiolatum*	Rambur, 1842	NR	LC

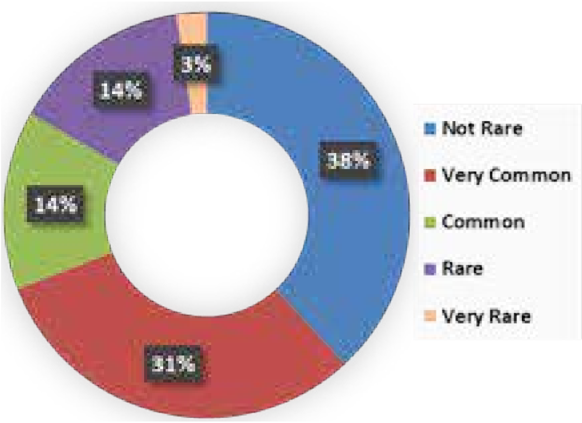

Figure 4. Local status of Odonata

(VC), 14% Common (C), 14% Rare (R), and 3% as Very Rare (R) (Tiple et al. 2013). As per the IUCN Red List, a total of 41 species have been classified as Least Concern (LC), while only a solitary species has been categorised as Data Deficient (DD).

DISCUSSION

The present investigation documented a total of 42 species in the Egra region, including 28 species of dragonflies and 14 species of damselflies, encompassing the two contiguous blocks of Purba Medinipur District (Image 43–46). By simply comparing the species count of previously studied checklist data on odonates from the different parts of Purba Medinipur by Prasad & Ghosh (1988), Jana et al. (2014), and Pahari et al. (2019), Libellulidae and Coenagrionidae family diversity was found higher among other families from all the study areas of Purba Medinipur district till date, which also stated in previous studies. Our study also shows that Libellulidae family was dominant and encompasses 22 species, like *Brachythemis contaminata* Fabricius, 1793, *Crocothemis servilia* Drury, 1770, *Diplacodes trivialis* Rambur, 1842, *Orthetrum sabina* Drury, 1773, *Pantala flavescens* Fabricius, 1798, *Rhyothemis variegata* Linnaeus, 1763, and *Tholymis tillarga* Fabricius, 1798. These species are commonly found in various habitats. According to our data, certain species within the family were found to be scarce in the study area, including *Macrodiplax cora* Brauer, 1867 and *Tramea basilaris* Palisot de Beauvois, 1805. *Gynacantha dravida* Lieftinck, 1960 and *Anaciaeschna jaspidea* Burmeister, 1839 belonging to the Aeshnidae family exhibit crepuscular behaviour and demonstrate active flight during the period of dusk. They tend to seek refuge in areas with abundant vegetation during daylight hours. Few dragonflies, like *Anax guttatus* Burmeister, 1839, *Anaciaeschna jaspidea* Burmeister, 1839, *Gynacantha dravida* Lieftinck, 1960, and *Ictinogomphus rapax* Rambur, 1842 are relatively larger in size. They are commonly observed in flight above waterbodies or perched on branches in the vicinity of such water sources. The *Epophthalmia vittata* Burmeister, 1839, of the Macromiidae family was only seen twice flying fast over the pond throughout the study period although it is generally considered to be abundant and common. The Coenagrionidae family exhibited the highest recorded species count among the damselflies. The observed species were categorized here as either 'very common' 'not rare' or 'rare' were present in various waterbodies, agricultural fields, and grasslands within the designated study areas. *Lestes viridulus* Rambur, 1842, a member of the Lestidae family, was observed only once during the study and was was categorized a very rare species within the family. The Platycnemididae family's species are predominantly observed in ponds with dense weed growth and surrounded by shaded vegetation and forests.

According to our research findings, the region has a thriving ecosystem characterised by a diverse range of Odonata species totalling 42 in number. However, excessive pesticide and herbicide use, the disappearance of small ponds and waterbodies, and the eradication of aquatic vegetation may have an impact on their population. Furthermore, people must recognize the importance of these aesthetically pleasing flying organisms in our ecological system.

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Image 1–28. Anisopteran species of the study area: 1—*Anax guttatus* | 2—*Anax indicus* | 3—*Gynacantha dravida* | 4—*Anaciaeschna jaspidea* | 5—*Ictinogomphus rapax* | 6—*Acisoma panorpoides* | 7—*Aethriamanta brevipennis* | 8—*Brachydiplax chalybea* | 9—*Brachydiplax sobrina* | 10—*Brachydiplax farinosa* | 11—*Brachythemis contaminata* | 12—*Crocothemis servilia* | 13—*Diplacodes trivialis* | 14—*Neurothemis fulvia* | 15—*Neurothemis tullia* | 16—*Orthetrum pruinosum* | 17—*Orthetrum sabina* | 18—*Pantala flavescens* | 19—*Zyxomma petiolatum* | 20—*Potamarcha congener* | 21—*Rhyothemis variegata* | 22—*Rhodothemis rufa* | 23—*Tholymis tillarga* | 24—*Tramea basilaris* | 25—*Tramea limbata* | 26—*Trithemis pallidinervis*| 27—*Urothemis signata* | 28—*Epophthalmia vittata*. © Asim Giri & Tarak Samanta.

Image 29–42. Zygopteran species of the study area: 29—*Agriocnemis pygmaea* | 30—*Agriocnemis kalinga* | 31—*Agriocnemis lacteola* | 32—*Ceriagrion cerinorubellum* | 33—*Ceriagrion coromandelianum*| 34—*Ischnura rubilio* | 35—*Ischnura senegalensis* | 36—*Pseudagrionr ubriceps* | 37—*Pseudagrion microcephalum* | 38—*Mortonagrion aborense* | 39—*Lestes viridulus* | 40—*Pseudocopera ciliata* | 41—*Copera marginipes* | 42—*Onychargia atrocyana*. © Asim Giri & Tarak Samanta.

Image 43–46. Different habitats of the study area: 1— Stagnant waterbody | 2— Roadside vegetation | 3—Agricultural fields | 4— Forest patch. © Asim Giri & Tarak Samanta.

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COMMUNICATION

Morpho-anatomy and habitat characteristics of *Xanthostemon verdugonianus* Náves ex Fern.-Vill. (Myrtaceae), a threatened and endemic species in the Philippines

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Abstract: This study provided insights into the morpho-anatomy of *Xanthostemon verdugonianus* Náves ex Fern.-Vill., a threatened species endemic to the Philippines. Sampling was conducted in its natural habitat with the presence of dominant vegetation and rehabilitated sites of the species. Quadrats were established to study the population size and document associated species & soil particle characteristics. The leaves are alternate in arrangement, reddish when young, and are hypostomatic with paracytic stomata. The distinctly thick cuticle and the compact spongy layer could be an adaptation to tropical island conditions. The stem and roots contain tissues manifesting secondary growth with secondary xylem and outer bark formation. The inflorescence is a corymb, and the flowers are bright red, with a prominent cup-shaped hypanthium, persistent lobe-shaped calyx, and a superior ovary. Fruit is a globular capsule round-ovoid in shape with a woody texture. Placental seeds are visible upon splitting matured fruits which are flattened and deltoid to semicircular shape. Twenty-nine species of plants belonging to 19 families were found to be associated with *X. verdugonianus*, with a mean abundance of eight species per plot. The ultramafic substrate was dominantly composed of medium sand particles, and the reddish color indicated the oxidation of metallic elements in the soil. Analyzing the morpho-anatomical features can help explain endemicity, survival, and adaptation to climate change.

Keywords: Associated flora, Dinagat Island, diversity, habitat, Ironwood, lowland forest, ornamental, soil types, ultramafic.

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Author contributions: The topic for research investigation, study design, workflow, and editing were performed by Dr. Jess H. Jumawan. The species collection of Xanthostemon verdugonianus and associated species were assessed by Arlyn Jane M. Sinogbuhan, Angie A. Abucayon and Princess Ansie T. Taperla. Morphoanatomical sectioning of plant samples, leaf section was performed by Arlyn Jane M. Sinogbuhan. Stem and root sectioning were conducted by Princess Ansie A. Taperla and Angie A. Abucayon. Data analysis including statistical analysis was performed by the second author. The manuscript was drafted initially by Arlyn Jane M. Sinogbuhan, Angie A. Abucayon and Princess Ansie T. Taperla under the guidance of the primary author.

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INTRODUCTION

The genus *Xanthostemon* F.Muell. (Myrtaceae) comprises approximately of 50 species of trees and shrubs (Ruales & Jumawan 2023) distributed in Australia, Malaysia, Indonesia, New Guinea, and the Philippines (Nazarudin et al. 2012; Nazarudin 2020). *Xanthostemon* species are grown as ornamental plants in parks and roadsides due to their colorful flowers that bloom throughout the year in the tropics (Nazarudin & Tsan 2018). Essential oils are present in the leaves of many *Xanthostemon* species found in Australia (Brophy et al. 2006). Oils can also be present in other plant organs, which could be the basis for many species used as medicinal plants (Nazarudin et al. 2015). In the Philippines, six species of *Xanthostemon* occur in the wild, of which five species are endemic and one introduced to the country (Ruales & Jumawan 2023). These are *X. verdugonianus* Náves ex Fern.-Vill., *X. speciosus* Merr., *X. fruticosus* Peter G. Wilson & Co, *X. bracteatus* Merr., *X. philippinensis* Merr., and *X. chrysanthus* (F.Muell.) Benth.. These species are collectively known as Philippine ironwood.

Xanthostemon verdugonianus is a dominant species in Dinagat Island, forming a distinct vegetation community compared to other species. This unique characteristic was observed in evaluating forest habitat types of Dinagat Island, Philippines (Lillo et al. 2019). *X. verdugonianus* can also be found in Surigao del Norte, Agusan del Norte, Tinago, Samar, Leyte, and Dinagat (Ocon et al. 2018; Sarmiento 2020). The common features of these areas are the ultramafic rocks and soils that are rich in heavy metals (Fernando et al. 2008; Malabrigo & Gibe 2020). It is a hardwood species used as timber posts for houses and materials for furniture. The reddish inflorescence in terminal branches blooms in an open canopy during dry seasons. The attractive reddish flowers are preferred as ornamental plants and are commonly planted in parks and along roadsides outside their natural habitat (Flora Fauna Web).

Xanthostemon verdugonianus is considered a threatened species and is assigned 'Vulnerable' status (DENR DAO 2017; Energy Department Corporation 2018), making this plant a conservation priority. Mining activities in Surigao province threaten its natural habitat. In particular, Dinagat Islands is a Mineral Reserve under Republic Act No. 391 issued in 1939 by the Department of Environment and Natural Resources (DENR) because of its rich mineral resources, metallic and non-metallic deposits in aluminous laterite, phosphate, limestone, siliceous, and gold depositions (Sarmiento 2018). There are few studies conducted to understand the morpho-anatomical traits of *X. verdugonianus*. Studying the anatomy of this species can help better understand its growth, development, cultivation, and economic importance. An essential application of the anatomical studies on plants and trees will be to identify which type of tissues help plants survive different stresses in their environment (Lubis et al. 2022). Understanding the anatomical features of endemic plants in their natural habitats can help project the extreme effects of global warming and climate change (Lynch et al. 2021). Thus, this study aimed to examine the morpho-anatomical description of *X. verdugonianus*, including its associated flora, species richness, abundance, and soil particle characterization.

MATERIALS AND METHODS

The study was conducted in two sites within Barangay Liberty, Gibusong Island Loreto, Dinagat Islands positioned at 10.424829°N, 125.492350°E (Site 1), 10.4377°N, 125.493517°E (Site 2) (Figure 1), with an annual temperature of 27.66 °C, humidity of 79.67%, and precipitation of 16.66 mm for the year 2022 (Visual Crossing Corporation 2022). Site 1 is approximately 700 m away from the shore at 105 m, while site 2 is around 400 m away from the shore and at 45 m (Image 1). The sampling areas are located on the east side facing the Pacific Ocean.

Study Area

This study was conducted on two sites. The first site was located in Purok 3, Sun-ok and the second site was located in Purok 1, Lu-ok (Figure 2). It was observed that Site 1 comprises naturally grown *X. verdugonianus* bearing fruits and flowers associated with taller trees and other vegetation. Site 2 is a habitat with rehabilitated *X. verdugonianus* associated with fewer trees and vegetation. Following the study of Lillo et al. (2019), the present study area falls within the lowland forest type, which was categorized into lowland tall forest (Site 1) and shrub forest (Site 2).

Morpho-Anatomical Description of *X. verdugonianus* Samples

Morphological measurements of the leaves, flowers, fruits, and seeds of *X. verdugonianus* were done following the method of Berghetti et al. (2019) with some modifications. Twenty samples of leaves were measured using the caliper to get the mean leaf

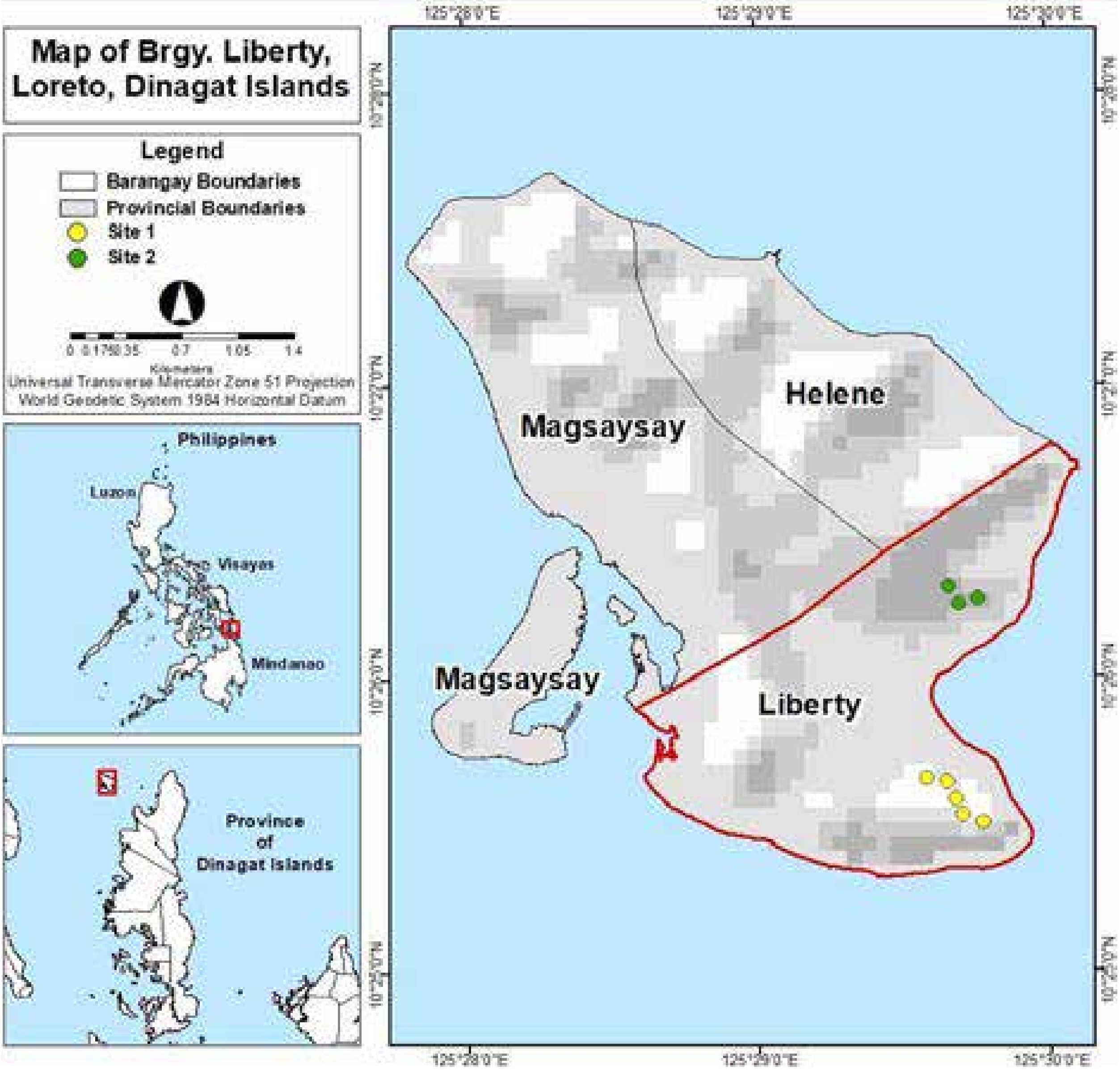

Figure 1. Map of Barangay Liberty, Gibusong Island Loreto, Dinagat Island, Philippines.

length (LL) and leaf width (LW). Randomly selected trees of *X. verdugonianus* were measured in terms of tree height using a tree pole and stem diameter using a tape measure. Photographs depicting the morphological features of the plant were taken using a Canon SX70 digital camera. Tree characteristics were measured in situ and expressed in metric units. Fruits, flowers, and seeds samples were collected, preserved in glycerine, and brought to the Biology Laboratory at Caraga State University for analysis. Flower and seed samples were measured using a digital caliper (mm) and dissecting microscope (KOPPACE) in the laboratory. The samples were collected in November 2022, and photographs of the plants were taken to aid an accurate description.

The fresh samples of *X. verdugonianus* were subjected to anatomical characterization following the method of Dubowsky (2009) and Sultana & Rahman (2020) with some modifications. The adopted procedure utilized stains, but in this study fresh plant samples showed the best results. A handheld microtome instrument (AYM brand Student Hand Microtome) was used for anatomical sectioning, and cross-sections were prepared from the stems, leaves, and roots. It was done by cutting into thin sections with a razor, mounting them on a glass slide, and observing under the microscope. The anatomical structures of some significant parts,

Image 1. Sampling sites showing naturally grown and rehabilitated *Xanthostemon verdugonianus*. © Arlyn Jane Sinogbuhan for 1A&B, Angie A. Abucayon for 1C and Vivian R. Badlis for 1D.

including the leaf, stem, and root of *X. verdugonianus*, were viewed, described, and photographed using the KERN compound microscope.

Field Sampling and Identification of Associated Species

A total of eight sampling plots were established in the two sites with dimensions of 10 x 10 m each. A purposive sampling was conducted across all sampling plots with identified naturally grown and rehabilitated *X. verdugonianus* in the area. The associated flora was determined in situ, and other species were verified using the identification guides of Fernando (2017) on the flora of Dinagat and Co's Digital Flora of the Philippines (Pelser et al. 2011). The species count data were summarized and used to derive abundance and species richness for biodiversity implications of species associated with *X. verdugonianus*. The PAST software (Hømmer et al. 2001) computed diversity values.

Soil particle characteristics in *X. verdugonianus* habitats.

Soil samples were collected within the established sampling plots for soil particle analysis. At least 300 g of soil samples collected at 10 cm depth (Mullet et al. 2014) were transported to Biology Department Laboratory, Caraga State University. Soil was air-dried in a well-ventilated area for 5–7 days. Completely dried samples were weighed at exactly 300 g each and subjected to soil particle characterization using a sieve (W. S TYLER brand) with the following sizes and descriptions: gravel (2 mm), very coarse sand (850 µm), medium sand (425 µm), fine sand 180 µm, very fine sand (150 µm), and silt or clay (<150 µm) (Jumawan et al. 2015).

RESULTS AND DISCUSSION

Morphological characteristics of *X. verdugonianus*

In its natural habitat, *X. verdugonianus* is a shrub to a tree with a mean height of 5.28 m and a mean stem diameter of 20.27 cm. Most of the individual samples are primarily shrubs, and few are trees, with a height ranging from 14–30 m (Image 2A). As observed, one of the unique character traits of *X. verdugonianus* was the rampant growth of new shoots with bright red regenerated leaves (Image 2D).

The leaves are simple and alternate in young and adult plants, with oval to elliptical lamina, glossy green on the adaxial and white greenish on the abaxial side. The leaf has a mean diameter of 4.5 cm and 8.6 cm in length (Image 2B). Young leaves are bright reddish, showing pinnate venation with visible secondary veins (Image 2E).

The inflorescence is a simple corymb, 3–6 flowered, bright red, found at the terminals of branchlets. Each flower is complete with sepals, petals, androecium, and gynoecium (Image 3A,B). A prominent cup-shaped hypanthium is connected to a sturdy pedicel (Image

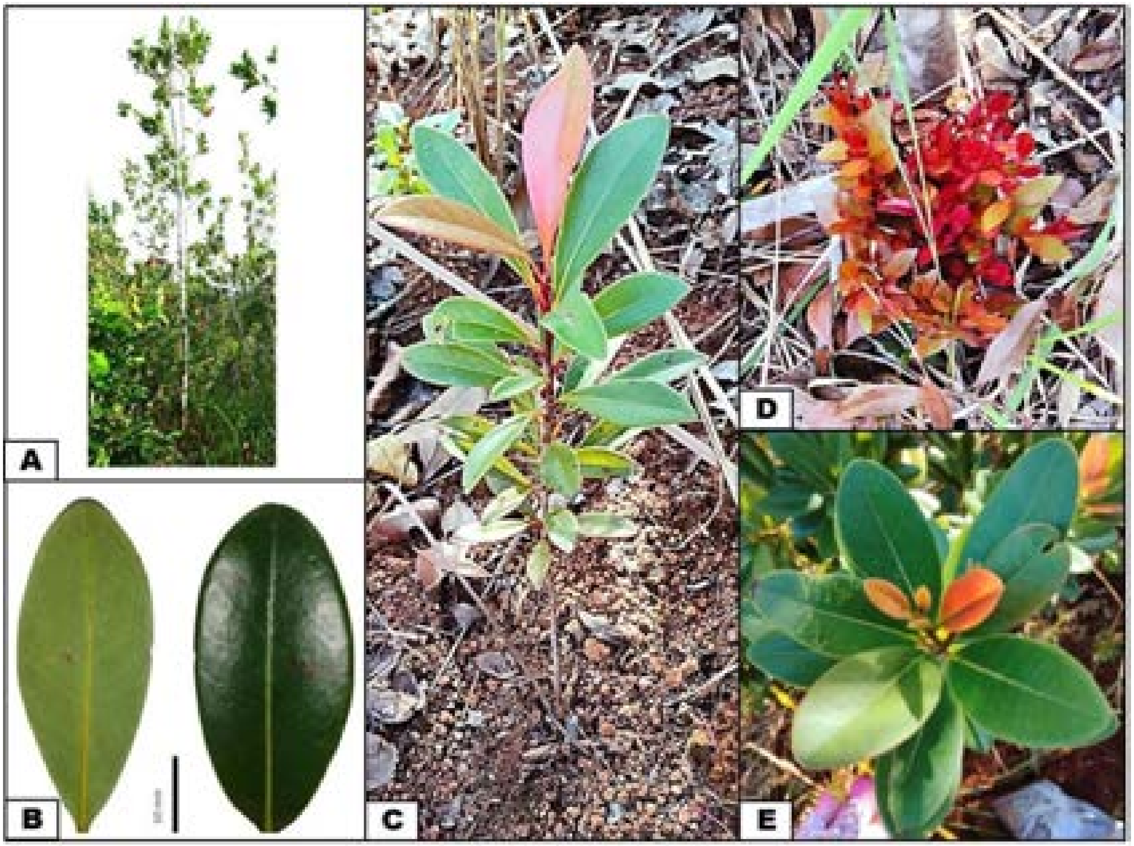

Image 2. Morphological Characterization of *Xanthostemon verdugonianus*: A—Tree | B—Leaves (adaxial and abaxial) | C—Juvenile stage | D—Newly develop branches or young branches | E—Axillary shoot (mature plant). © Angie A. Abucayon for 2A, Jeco Jade Ruales for 2 B and Arlyn Jane M. Sinogbuhan for 2 C-E.

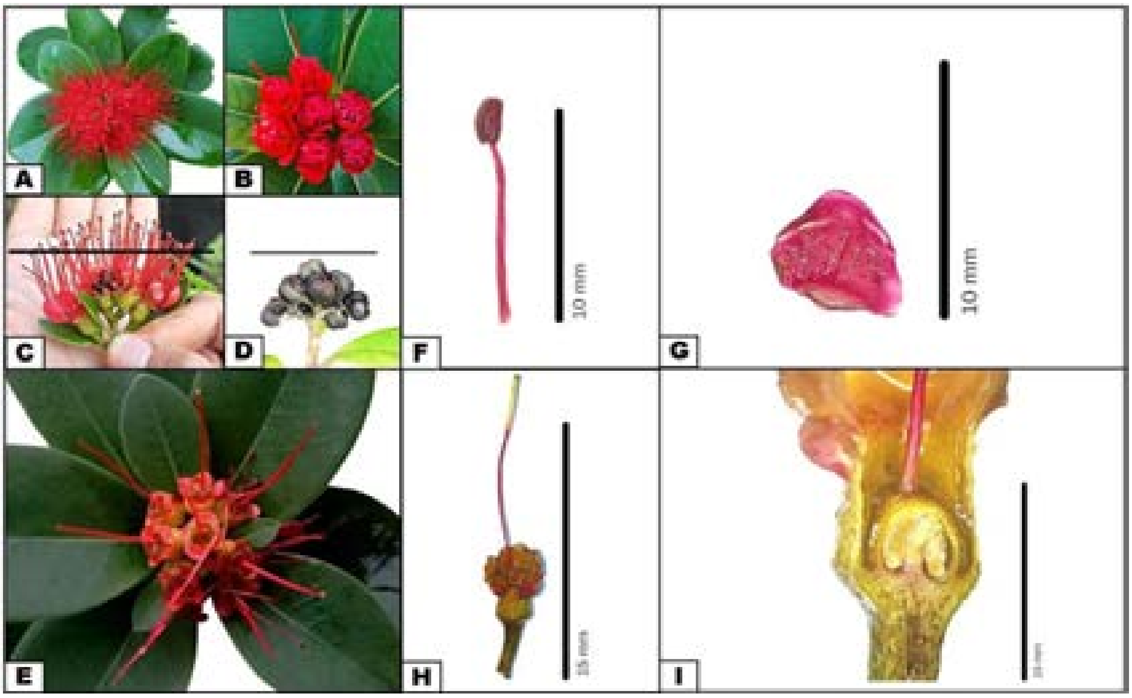

Image 3. *Xanthostemon verdugonianus* flower morphology: A,B—Flower bud | C,D—Flower Inflorescence | E—Complete flower | F—Anther and filament (Stamen) | G—Petals (corolla) | H—Style | I—Ovary. © Angie A. Abucayon for 3 A & D, Arlyn Jane M. Sinogbuhan for B-C & E and Vivian Badlis for 4 F-I.

3C,D). The calyx is persistent (Image 3E). The stamens are 18–25, red, 1.5–1.9 mm long (Image 3F). Petals are 4–8, red, slightly triangular in shape, 4.5–6.7 mm long, 4.3–6.4 mm broad (Image 3G). The style is 6.9–12.6 mm long (Image 3H). The ovary is enclosed in the hypanthium connected to the pedicel. Ovaries are almost superior (Wilson 1990), 2–3 locular, glabrous, 5.4–8.8 mm long, and 5.1–9.5 mm in diameter (Image 3I).

The fruit is an ovoid-globular capsule, measuring 10–12 mm in diameter and 4.4–5 mm long (Image 4A). Seeds are bilaterally flattened and deltoid to semicircular in outline (Image 4C). Mature fruits dehisce open, exposing the seeds (Image 4D). The capsule is woody, 2–4-lobed (Image 4E).

Anatomical Characterization of *X. verdugonianus*

The leaf. The depicted section is the adaxial surface of a leaf covering the lamina and midrib portion. The midrib cross-section has prominent xylem and phloem. The upper and lower epidermis showed similar thickness with distinct cuticle layers (C) (Image 5). The mesophyll consists of a palisade and spongy layer. The mesophyll layer is a conspicuously greenish layer composed mainly of compact palisade box shape cells with no distinct spongy layer of loosely arranged cells observed in the leaf cross-section. The stomata are found in the lower epidermis with a diameter of about 240 µm, hypostomatic with a paracytic type of stomata (Image 6).

The study's leaf anatomy findings are the same observed in the family Myrtaceae. According to Ali et al. (2009), the leaf section of Eucalyptus (family Myrtaceae) from the Faisalabad region showed epidermis and cuticle were similar to the present study. Another similar observation in *Eugenia luschnathiana* (Myrtaceae) was reported by Lemos et al. (2018). Nazarudin et al. (2015) study on the anatomy of *Xanthostemon chrysanthus* treated with PBZ (paclobutrazol) reveals tightly arranged palisade and mesophyll cells on the leaf which is similar to the findings on the *X. verdugonianus*. As Ali et al. (2009) reported, the thicker epidermis and the thick cuticle could be adapted to island conditions in tropical environments. According to Savaldi-Goldstein et al. (2007) and Domínguez et al. (2011), the cuticle mechanically protects plants by reducing the impact of external stresses such as wind or heavy rain and, in conjunction with the epidermis, preventing tissue breaking and participating in the control of organ growth.

The stem. Samples performed for stem anatomy were taken from shoot tips of mature shrubs in their natural habitat. The cross-section of the stem was generally smooth and circular, with an indication of secondary growth. The section of the stem (Image 7) shows the thick periderm (Pr), which later forms the outer bark—followed by the primary phloem (Ph[1]), and secondary

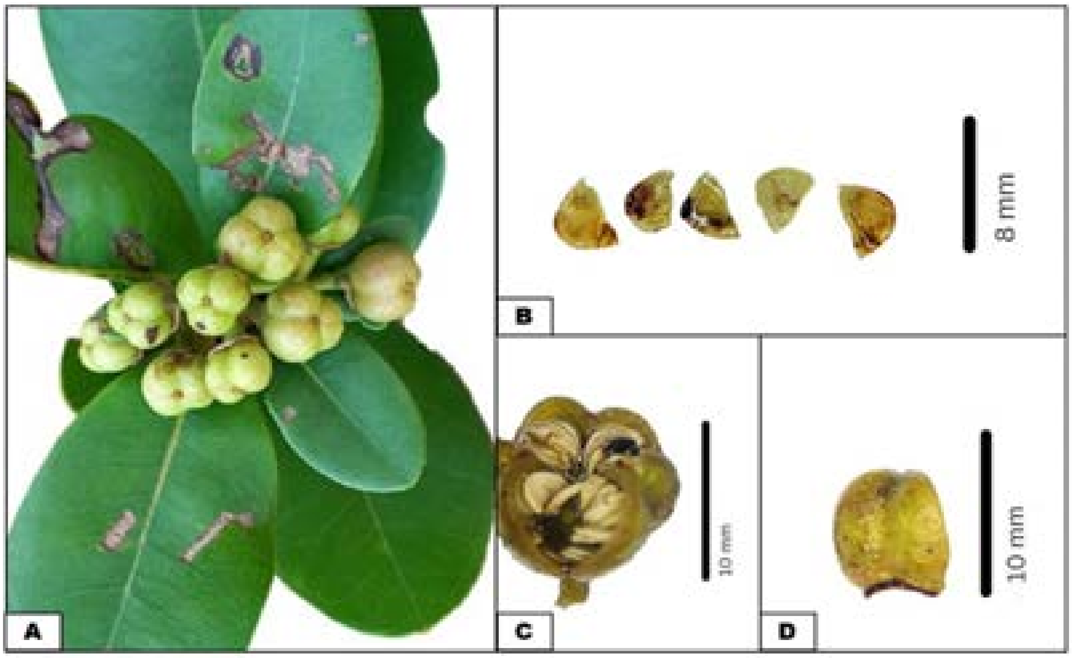

Image 4. Fruit morphology of *Xanthostemon verdugonianus*: A—Fruiting twig | B—Seeds | C—Dehisced fruit showing the seeds | D—A valve of the fruit shell. © Angie A. Abucayon for 4 A and Vivian Badlis for 4 B-D.

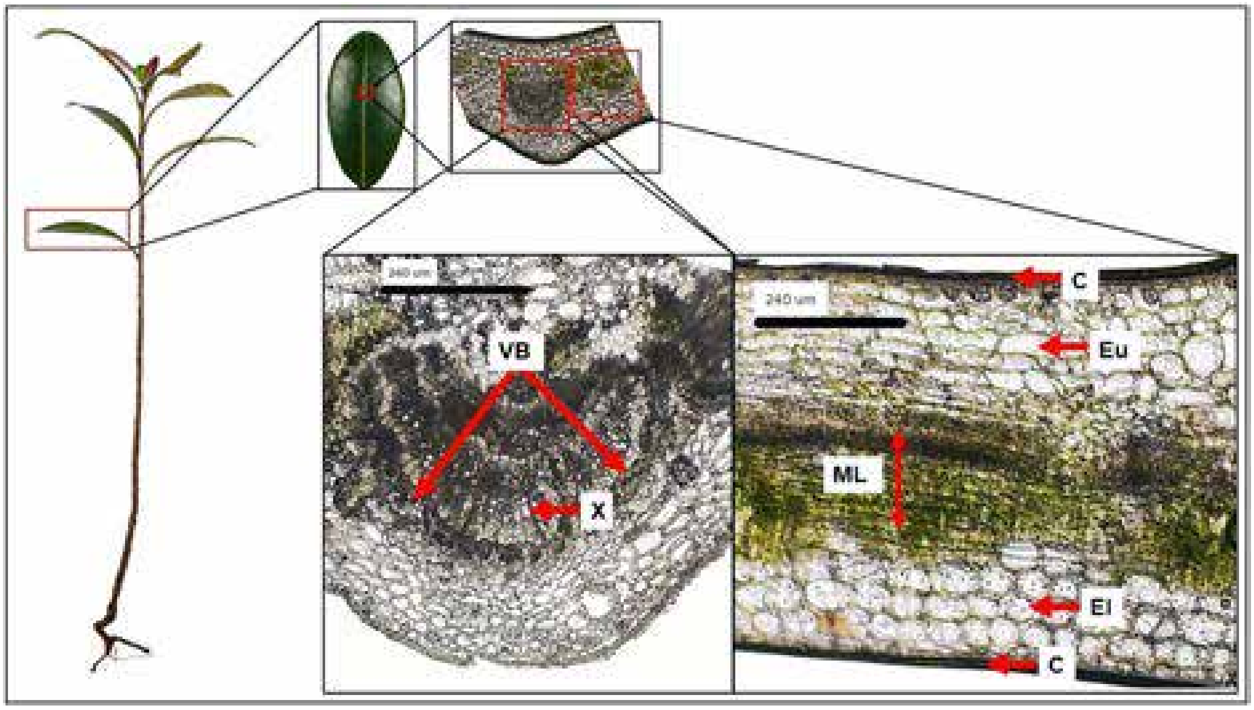

Image 5. Leaf anatomy of *Xanthostemon verdugonianus* showing the various tissues: VB—Vascular bundle | X—Xylem | C—Cuticle | Eu—Upper epidermis | ML—Mesophyll layer | EI—Lower epidermis. © Arlyn Jane M. Sinogbuhan.

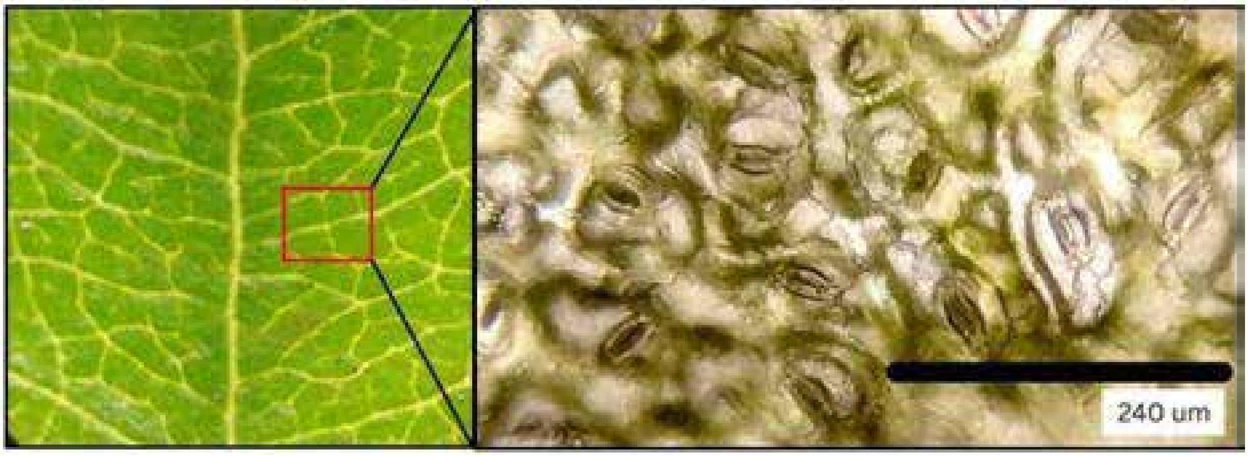

Image 6. Leaf lower epidermis of *Xanthostemon verdugonianus*: Stomata- paracytic. © Arlyn Jane M. Sinogbuhan.

phloem (Ph^2). These tissues are undifferentiated due to their similar composition. The vascular cambium (Vc) is sandwiched between the phloem and the xylem. Xylem rays (Xr) appear as dark lines and vessel elements (V) emerge as distinct solitary-circular cells dispersed within the premises of the secondary xylem (X^2). The less intact primary xylem (X^1) is noticeable as it shows small-circular compacted cells near the pith. The pith (P), which is positioned at the innermost part of the stem composed of irregular parenchyma cells showing a less clearly stellate shape (Image 7).

The findings of the stem anatomy of *X. verdugonianus* were compared to some studies of the Myrtaceae family. The stem in the present study lacks a secretory cavity similar to *Eugenia pyriformis* Cambess in the study Armstrong et al. (2012). However, the presence of secretory cavities is recorded to be found in stems of some *Eucalyptus* species, such as *E. grandis*, *E. urophylla*, and *Eucalyptus saligna*, measuring 78, 45, and 40–110 µm in diameter, respectively, were included in the study of Saulle et al. (2018) and Brisola & Demarco (2011). The xylem forms inward while the phloem forms outward, as

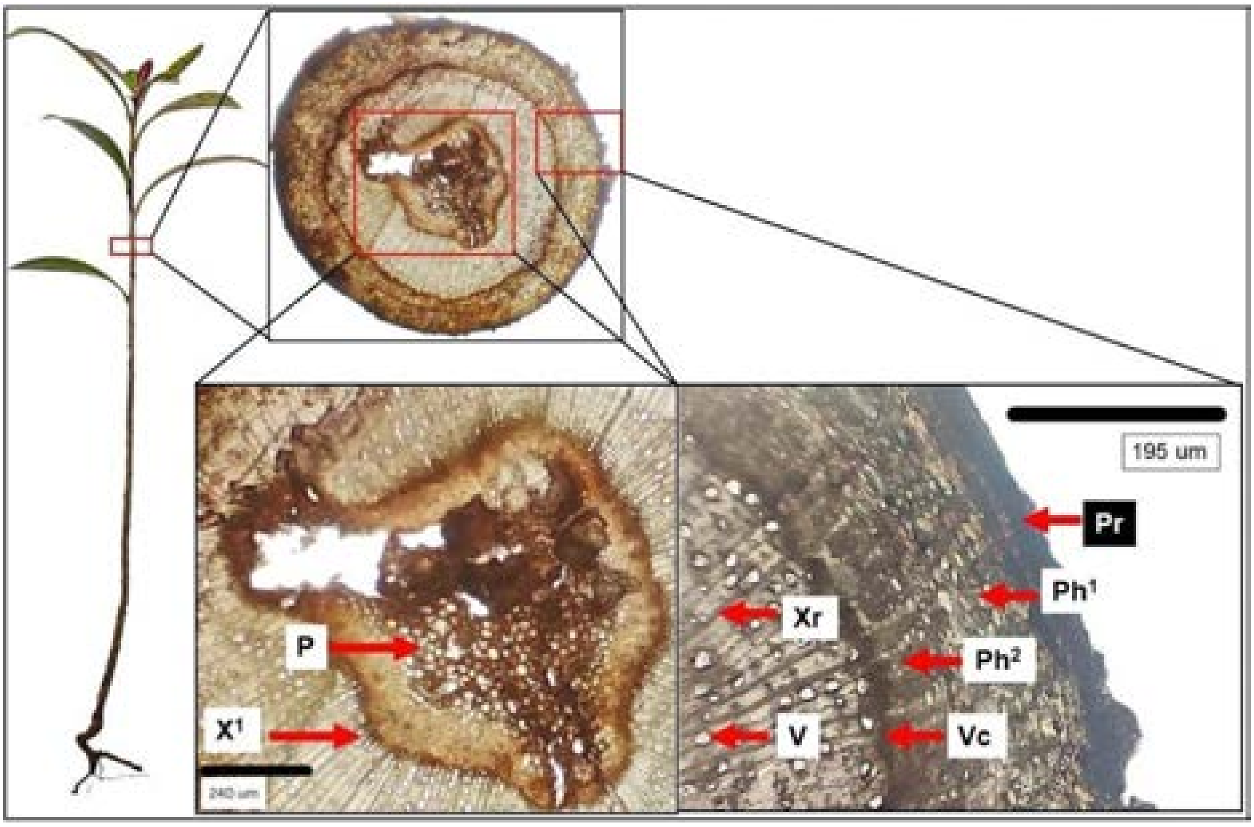

Image 7. Stem anatomy of *Xanthostemon verdugonianus*: P—Pith | X^1—Primary xylem | X^2—Secondary xylem | V—Vessel element | Xr—Xylem rays | VC—Vascular cambium | Ph^2—Secondary phloem | Ph^1—Primary phloem | Pr—Periderm. © Princess Ansie T. Taperla.

observed in *Eucalyptus cinerea* (Pauzer et al. 2021). The less clearly stellate pith shape observed in this study was similar to the results of *E. microcorys, E. pilularis*, and *E. marginata* Sm. in the study by Bryant & Trueman (2015).

The roots. The woody root of the juvenile *X. verdugonianus* was examined in the study and is found to be positively geotropic. Anatomical features are shown in Image 8 and appear to have a distinct demarcation of epidermal, cortical, and vascular regions. The cross-section shows the unilayered periderm (Pr) consists of thin-walled cutinized cells as the outermost protective layer of the root, followed by the primary phloem (Ph^1) characterized by round and oval shape, clumped (usually 5–10) in a linear manner and secondary phloem (Ph^2) portray a much smaller round and oval cells, also arranged in a linear manner (usually 3–5 in a clump) designated just before the vascular cambium. Dividing the phloem and the xylem is the vascular cambium (Vc) appears to have undistinguished cells. The secondary xylem (X^2) covers a larger part of the root, displaying round to oval vessel elements irregularly scattered and the xylem rays (Xr) display a distinct line along the periphery of the stele. The primary xylem (X^1) encloses the remnants of the pith at the innermost part of the root, which was pushed to the center due to the production or development of the secondary xylem (Evert 2006). The primary and secondary phloem is also pushed in the opposite direction of the primary vascular system, which will later become the woody part of the root and serve as protection along with the periderm (Pr).

There is a limited study on the anatomical structure of *X. verdugonianus* in its natural habitat, and in this study, the noticeable feature found in the root are the phloem fibers (see white arrow in Image 8) along the vascular cambium. This species is endemic and vulnerable in its ecological status and data provided anatomical descriptions as baseline information. Findings such as the solitary vessel elements and the conspicuous xylem rays throughout the length of the secondary xylem were also observed in the root anatomy of *Syzygium* sp. (Rahayu & Husodo 2020) and *Syzygium cumini* Skeels, a vascular plant under the family Myrtaceae (Singh & Misra 2015).

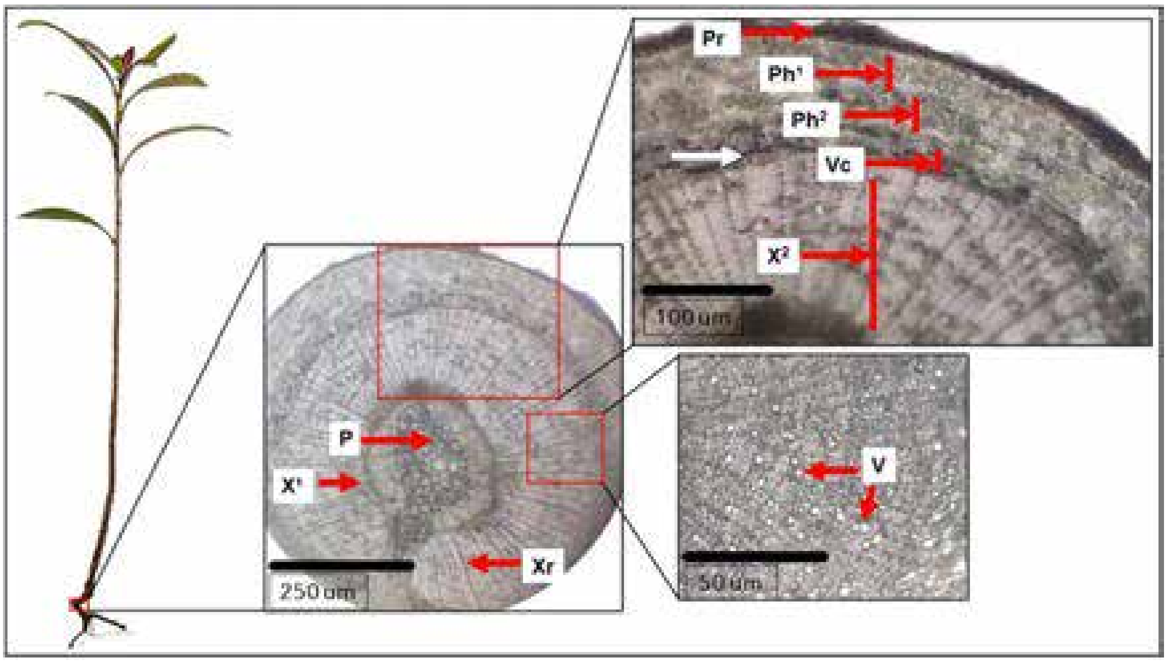

Image 8. Root anatomy of *Xanthostemon verdugonianus*: P—Pith | X¹—Primary xylem | X²—Secondary xylem | V—Vessel element | Xr—Xylem rays | VC—Vascular cambium | Ph²—Secondary phloem | Ph¹—Primary phloem | Pr—Periderm. © Angie A. Abucayon.

Table 1. Plant associations of *Xanthostemon verdugonianus* in Loreto, Dinagat Island.

Family name	Scientific name number of individual	Total number of individual	Present in Site 1	Present in Site 2
Anacardiaceae	*Buchanania arborescens* F. Muell.	7	*	*
	Mangifera indica L.	2		*
Apocynaceae	*Alstonia parvifolia* Merr.	6	*	
	Kibatalia stenopetala Merr.	1		*
	Kibatalia sp.	7		*
Bignoniaceae	*Radermachera pinnata* Seem.	2	*	
Burseraceae	*Canarium euryphyllum* var. *euryphyllum*	5	*	
Calophyllaceae	*Calophyllum inophyllum* L.	1		*
Ebenaceae	*Diospyros* sp.	8	*	
Gnetaceae	*Gnetum gnemon* L.	8	*	*
Melastomataceae	*Medinilla myrtiformis* (Naudin) Triana	6	*	
	Medinilla sp.	1	*	
	Melastoma malabathricum L.	1		*
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	1		*
Myrtaceae	*Tristaniopsis decorticata* (Merr.) Peter G. Wilson & J.T. Waterh.	4	*	*
Moraceae	*Artocarpus pinnatisectus* Merr.	1	*	
Rubiaceae	*Pavetta williamsii* Merr.	1	*	
	Timonius valetonii Elmer	8	*	
Pandanaceae	*Freycinetia* sp.	2	*	
	Pandanus dinagatensis Merr.	2	*	*
	Sararanga philippinensis Merr.	1		*
Pentaphragmataceae	*Pentaphragma* sp.	2		*
Phyllantaceae	*Phyllanthus ramosii* Quisumb. & Merr.	8	*	
	Phyllantus sp. 1	6	*	
	Phyllantus sp. 2	2	*	
Podocarpaceae	*Podocarpus* sp.	7	*	
Sapindaceae	*Guioa diplopetala* (Hassk.) Radlk.	6	*	
	Guioa koelreuteria (Blanco) Merr.	8	*	
Thymelaeaceae	*Wikstroemia indica* (L.) C.A. Mey.	8	*	

*represents the presence of species in the site.

Table 2. Species richness and abundance of plants associated with *Xanthostemon verdugonianus* in Barangay Liberty, Loreto Dinagat Island.

	Site 1					Site 2			Average
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	
Species richness	11	11	4	10	8	6	6	8	8
Abundance	77	62	44	23	15	35	131	53	55

Table 3. Mean values of Soil Particles Obtained in Barangay Liberty, Loreto, Dinagat Island.

Soil Particle	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Soil obtain (g)	Percentage (%)
Gravel	44	69	124	114	78	107	62	73	671	28.74
Very coarse sand	55	78	57	100	66	109	80	71	616	26.39
Medium sand	40	133	115	85	101	73	132	147	826	35.38
Fine sand	40	10	0.4	77	39	8	18	8	200.4	8.58
Very fine sand	0	0	0	4	6	0	0	0	10	0.43
Silt or clay	0	0	0	0	11	0	0	0	11	0.47

Associated Flora to *X. verdugonianus* in its habitat

Twenty-nine species under 19 families of vascular plants were identified (Table 1) in the study plots of *X. verdugonianus*. The family Phyllantaceae is the most presented with 16 individual species. The least represented families were Meliaceae and Moraceae, each with one species. Phyllantaceae family included *Phyllanthus ramosii* Quisumb. & Merr. and two other unidentified species of *Phyllanthus*. The other associated plants belonging to other families included *Tristaniopsis decorticata* (Merr.) Peter G.Wilson & J.T.Waterh., *Alstonia parvifolia* Merr., *Artocarpus pinnatisectus* Merr., *Pavetta williamsii* Merr., *Timonius valetonii* Elmer, *Buchanania arborescens* F.Muell., *Calophyllum inophyllum* L., *Canarium euryphyllum* G.Perkins var. euryphyllum, *Diospyros* sp., *Freycinetia* sp., *Gnetum gnemon* L., *Guioa diplopetala* (Hassk.) Radlk., *Guioa koelreuteria* (Blanco) Merr., *Kibatalia stenopetala* Merr., *Kibatalia* sp., *Mangifera indica* L., *Medinilla myrtiformis* (Naaudin) Triana, *Melastoma malabathricum* L., *Pandanus dinagatensis* Merr., *Podocarpus* sp., *Radermachera pinnata* Seem., *Swietenia mahagoni* (L.) Jacq., *Wikstroemia indica* (L.) C.A.Mey., and *Sararanga philippinensis* Merr. The sampling was considered a rapid procedure conducted in a short period. By increasing sampling intensity, more species could be associated with *X. verdugonianus* in other areas.

Species richness and abundance of associated flora

Species richness, defined as the number of species per unit area, is perhaps the most straightforward measure of biodiversity (Brown 2003). According to Fedor & Zvaríková (2019), species richness presents a measure of the variety of species based simply on a count of the number of species in a particular area. Associated species to *X. verdugonianus* in Barangay Liberty, Loreto, Dinagat Island has an average species richness of 8. It was observed that plants that thrive in this area had developed morphological adaptations to lessen their water intake and water loss (Brady et al. 2005). The abundance of species recorded in plot 1 (45), plot 2 (40), plot 4 (17), plot 7 (16), and plot 8 (13), respectively, where *X. verdugonianus* dominated in the area (Table 2).

Soil Particle Characteristics Sampled from *X. verdugonianus* habitats

As observed in the field, *X. verdugonianus* grow in reddish soils of Surigao del Norte, Philippines. The soil type in the province is derived from serpentinized ultramafic rocks composed of Mg, Fe, Cu, Co, Ni, and Cr elements subjected to weathering of olivine, pyroxene, and chromite minerals (Ocon et al. 2018). The reddish soil coloration is due to oxidized iron minerals resulting in red color commonly referred to as rust (Pérez-Guzmán et al. 2010). Aside from iron, the red soils contain the heavy metals preferred for mining activities (Navarrete & Asio 2011). Similar ultramafic substrate in Palawan Island, Philippines where another species of *Xanthostemon speciosus* was observed (De Castro et al. 2020). Medium sand has the most abundant percent value, 35.38%, followed by gravel (2 mm) which is 28.74%, and very coarse sand (850 µm), with a percent value of 26.39%, respectively (Image 9). The

Image 9. The soil type in Barangay Liberty, Loreto, Dinagat Island: A—Gravel | B—Very coarse sand | C—Medium sand | D—Fine sand | E—Very fine sand | F—Silt or clay. © Angie A. Abucayon.

least mean value of all the substrates was very fine sand (150 µm) with a percentage value of 0.43% (Table 3). Few articles described soil particle characteristics that are preferential to the growth and development of *X. verdugonianus*. The study provides baseline information on soil particles of the species in the sampling area. The data suggested that the bigger soil particle size consisting of medium sand, very coarse sand, and gravel is preferable to the growth of *X. verdugonianus.*

CONCLUSION

Xanthostemon verdugonianus is a threatened species endemic to the Philippines. The plants grow in the mineral-rich red soils and are characterized by their reddish young foliage, red flowers arranged in red corymbs in the terminals of branches. The woody, dehiscent capsules are 2–4-lobed and have many flattened seeds. The leaf is arranged alternately in both young and adults. With corymb inflorescence, the complete flower of *X. verdugonianus* possessed a cup-shaped hypanthium and semi-circular calyx. The ovoid-globular fruit consists of a woody covering and the seeds are bilaterally flattened and deltoid to semicircular in shape. The leaf anatomy was observed to have a thick cuticle on the adaxial side that displays the characteristic of plants to adapt to island conditions in tropical environments. The stem shows secondary growth, with a pith arranged in a less clearly stellate shape. Xylem rays and the vessel elements scattered along the length of the secondary xylem are the distinctive features of its stem and root anatomy. Twenty-nine associated plant species belonging to 19 families were recorded in the study area. Soil substrate mainly comprises medium sand particles, and reddish coloration could be due to oxidized metallic elements. Distinct anatomical characteristics of *X. verdugonianus*, such as the compressed palisade and spongy layer of the leaf midrib cross-section and the irregular shape of the pith in the stem cross-section, may be due to environmental stress like the presence of heavy metal in the soil, limited water intake, and temperature fluctuations in the island conditions. To better understand the unique features and adaptations of *X. verdugonianus*, detailed morpho-anatomy studies of the plants growing in the rainforest and island conditions are needed. The effects of heavy metals in the habitats on the plants should also be investigated.

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COMMUNICATION

The epiphytic pteridophyte flora of Cooch Behar District of West Bengal, India, and its ethnomedicinal value

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Abstract: Cooch Behar, located in the northeastern part of West Bengal, has a rich pteridophytic flora. The present field study was undertaken during January 2021 to September 2022 to document the epiphytic pteridophyte flora of the district and record ethnomedicinal uses, which had not been studied previously. Nine epiphytic species of pteridophytes belonging to six genera and three families were recorded, with Polypodiaceae being the dominant family represented by seven species (4 from genus *Pyrrosia*). Seven epiphyte species were used by ethnic communities and traditional healers to treat 10 different types of diseases, including common cough and cold, and jaundice. This study adds five epiphytic species of pteridophytes to previous records from Cooch Behar District.

Keywords: Ethnic communities, ferns and fern allies, medicinal plants, traditional knowledge, vertical distribution.

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INTRODUCTION

Pteridophytes are derived from ancient lineages dating back 400 million years, which dominated the earth's surface about 280–230 million years ago. But modern fern floras and families are highly evolved and constitute a fairly prominent part of the present-day vegetation of the world. Hassler (2004–2023) estimates that there are about 13,046 species of ferns and lycophytes throughout the world. In India, between 1,150 and 1,270 species of pteridophytes consisting of 33 families and 130 genera are reported (1,267 estimated by the Botanical Survey of India 2023), of which c. 50 species are endemic to India (Fraser-Jenkins 2008). According to Fraser-Jenkins et al. (2017, 2018, 2021), altogether there are about 1,135 species including 42 exotics and 53 further subspecies, in the Indian subcontinent and in West Bengal, approximately 528 species are reported. Epiphytic pteridophytes constitute an important part of the fern flora (Devi et al. 2007) and contribute to higher phytodiversity in vertical space in tropical rain-forest (Page 1979). Approximately, 29% of all fern species are epiphytes (Kress 1986).

Medicinal plants have been used in healthcare since time immemorial. Even today, more than 80% of the population in developing countries are directly dependent on ethnomedicine for healthcare (Farnsworth et al. 1985; WHO 2003). Pteridophytes have been considered as a source of medicine since ancient times but remain relatively under explored. Ancient classical work of Theophrastus (327–287 B.C.) and Dioscorides (100 A.D.) regarding ethno-medicinal values of pteridophytes is well known (Corne 1924). Sushrata and Charaka in their Samhitas (100 A.D.) also mentioned the medicinal utility of some pteridophytic plants.

Numerous ethnomedicinal studies (Caius 1935; Nayar 1959; Singh 1973; May 1978; Joshi 1997; Dhiman 1998; Sharma 2002; Srivastava 2007; Rout et al. 2009; Benniamin 2011; Giri et al. 2021; Dey & Bhandari 2022) on pteridophytes have been conducted in different parts of India over the past nine decades, but unfortunately, scientific documentation of the pteridophytic flora and its ethnomedicinal value in Cooch Behar District of West Bengal is very limited (Biswas 1956; Bandyopadhyay et al. 2006; Biswas et al. 2013).

Although the flora is limited compared to the higher regions further north, it is nevertheless known for its rich floristic composition and traditional culture. The district is still under developing status and rural people depend mostly on medicinal plants to treat common physical problems.

Keeping the importance of medicinal plants in the district in mind, the present study has been designed to explore uses of the epiphytic pteridophyte flora as medicinal plants among the ethnic people of Cooch Behar District. Scientific documentation of the fern flora will definitely enrich the floristic database of the state as well as of India and documentation of ethnomedicinal knowledge can be used as a reference for future research on formulation of new drugs and pharmaceutical products.

MATERIALS AND METHODS

Study area

Cooch Behar District (Figure 1) is situated in the foothills of the eastern Indo-Himalaya. Geographically the district lies between 26.6055°N to 26.9630°N and 89.9097°E to 89.7955°E and is bounded by the district of Jalpaiguri and Alipurduar in the north, Dhubri and Kokrajhar district of Assam in the east and the international border in the form of the Indo-Bangladesh boundary in the west as well as in the south. The elevation of the district ranges 39–76 m. The area of the district is 3,387 km^2, and constitutes 3.82% of the land mass of the state of West Bengal. The district is still fairly rich in forest canopy (10.31% of the total land mass) and in terms of forest canopy density, the forest areas are mostly open forests with a few areas under moderately dense forest; while the district lacks very dense forests areas (Das 2020). The forests are a mixture of deciduous elements with some evergreen trees.

Data collection

A total of four field visits were completed at different seasons between January 2021 and September 2022 documenting the epiphytic pteridophyte flora and to collect information on the ethnomedicinal uses of pteridophytes in the areas studied. Plant specimens were collected from their host plants with the help of a telescopic pole with a picker and sometimes with the assistance of a local tree climber. Digital photographs of the plant specimens were also taken wherever possible. Routine methods of plant collection and herbarium techniques (Jain & Rao 1977) have been followed in the study. Identification of all the collected plant specimens was made using relevant floras and standard literature (Beddome 1883, 1892; Prain 1903; Ghosh et al. 2004; Fraser-Jenkins et al. 2017, 2018, 2021) and proper nomenclature was maintained following IPNI (2023).

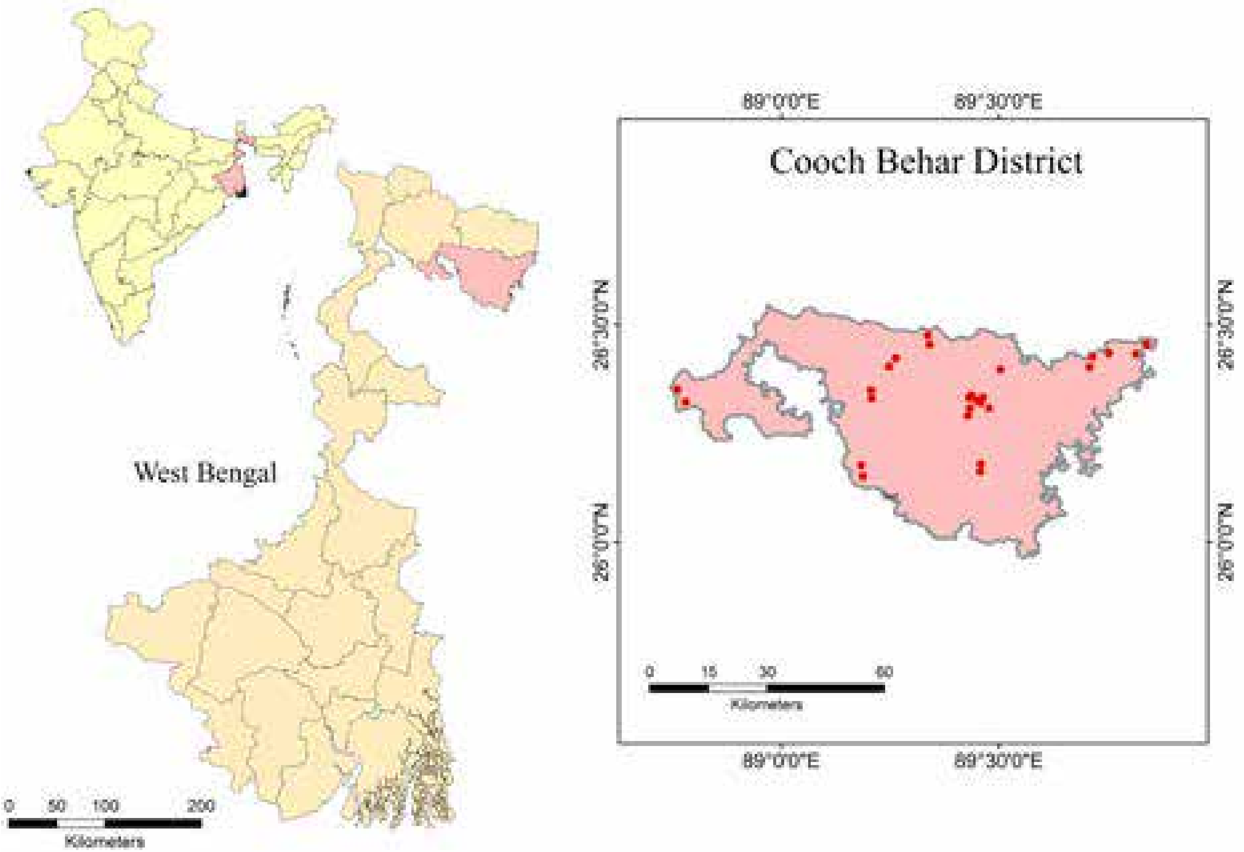

Figure 1. Map of Cooch Behar District showing sample collection sites (red dots) (Map prepared using an open source QGIS Desktop 3.22).

Voucher specimens were deposited in the Department of Botany, A.B.N. Seal College, Cooch Behar.

The ethnomedicinal data were collected through in-depth interviews with the knowledgeable local people of the ethnic communities and with traditional healers with the help of pretested semi-structured questionnaires (As per Sajem 2010). The questionnaire included information concerning plant local name, plant parts used, uses, process of preparation of medicine either individually or in combination with other plant parts, and mode of application and dosages to treat a particular disease(s). Prior informed consent (PIC) was taken from each informant before interview.

RESULTS AND DISCUSSION

The diversity and ethnomedicinal uses of epiphytic pteridophytes by different ethnic communities are presented in Table 1. The species collected are arranged in alphabetical order according to families and then according to genus and species within each family. Information regarding scientific name, family, localities of collections, and ethnomedicinal uses and mode of application for each species have also been provided.

A total of nine species of epiphytic pteridophytes belonging to six genera and three families (Table 1; Figure 2) were recorded during the field visits. Among these the dominant plant family was Polypodiaceae, represented by seven species (77.78%). Psilotaceae and Vittariaceae (Pteridaceae) were represented by a single species (11.11%) each. The genus *Pyrrosia* is represented by highest number of species (four species; 44.44%). They were mostly found to grow on trees of *Samanea saman* (Jacq.) Merr., *Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders, *Shorea robusta* C.F.Gaertn., and *Tectona grandis* L.f., among others. Biswas (1956) reported 24 species of pteridophytes from Cooch Behar, of which five species were epiphytic. Out of five epiphytic species, four species, *Drynaria quercifolia*, *Leptochilus axillaris*, *Pyrrosia adnascens*, and *Psilotum nudum* were common. In comparison to the report by Biswas (1956), the present study has revealed five more epiphytic pteridophytes from the district. Bandyopadhyay et al. (2006) reported the occurrence of *Psilotum nudum* from the same studied area as was

Table 1. List of epiphytic pteridophytes and their uses by ethnic people of Cooch Behar District.

	Scientific name	Localities	Parts used	Preparation	Uses/ application	Mode of administration	Used by
1	*Drynaria quercifolia* (L.) J.Sm. [Polypodiaceae]	Cooch Behar; Rasik Bil; Tapurhat; Sitalkuchi; Mathabhanga; Baneswar; Haldibari	Whole plant	Decoction	Used to treat jaundice, fever, throat infection (itchy throat), dysentery and joint pain.	Oral	Rajbanshi, Rava, Santhals
			Rhizome	Paste	Used to treat body pain.	Topical	
2	*Leptochilus axillaris* (Cav.) Kaulf. [Polypodiaceae]	Tapurhat; Takagach	-	-	Not yet known.	-	-
3	*Microsorum punctatum* (L.) Copel. [Polypodiaceae]	Cooch Behar; Rasik Bil; Tapurhat; Sitalkuchi; Mathabhanga; Haldibari	Leaves	Decoction	Used to treat dysentery and constipation.	Oral	Rajbanshi, Rava
4	*Pyrrosia adnascens* (Sw.) Ching [Polypodiaceae]	Cooch Behar; Tapurhat; Sitalkuchi; Ghoskadanga; Rasik Bil	Rhizome	Decoction	Used to treat cough and cold.	Oral	Rajbanshi, Rava
5	*P. flocculosa* (D.Don) Ching [Polypodiaceae]	Rasik Bil; Jorai	-	-	Not yet known.	-	-
6	*P. lanceolata* (L.) Farw. [Polypodiaceae]	Rasik Bil; Tapurhat, Putimari Baksibas	Leaves	Paste	Stop bleeding from cut wound.	Topical	Santhals, Oraon
			Leaves	Decoction	Used to treat cough and cold, throat infection and urinary disorder.	Oral	Santhals, Oraon
7	*P. piloselloides* (L.) M.G.Price [Polypodiaceae]	Cooch Behar; Rasik Bil	Leaves	Decoction	Used to treat cough and cold.	Oral	Rava, Santhals
8	*Psilotum nudum* (L.) P.Beauv. [Psilotaceae]	Cooch Behar	Whole plant	Decoction	Used to heal cuts and wounds.	Topical	Rajbanshi
9	*Vittaria elongata* Sw. [Vittariaceae (Pteridaceae)]	Cooch Behar; Chhat Singimari	Leaves	Paste	Used to treat joint pain.	Topical	Santhals

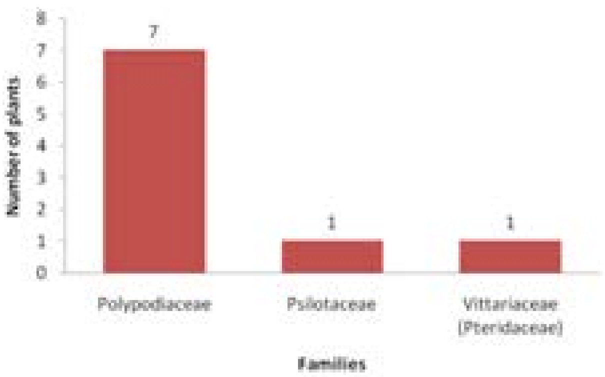

Figure 2. Family-wise number of ethnomedicinal pteridophytes of Cooch Behar District, West Bengal.

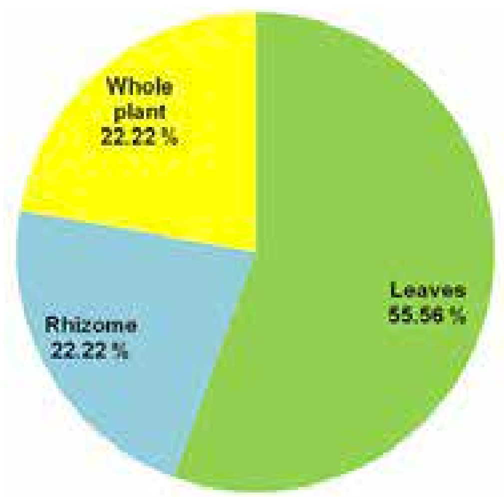

Figure 3. Plant parts used for herbal preparation by the ethnic communities of Cooch Behar.

reported earlier by Biswas (1956). Biswas et al. (2013) only recorded list of pteridophytic families claiming 36 species of pteridophytes growing at Rasik Beel region of Cooch Behar district but no other information or names of species was given.

Out of nine epiphytic pteridophytes, seven species were found to be used by ethnic communities and traditional healers in the studied area to treat 10 (Table 1) different types of physical ailments ranging from common cough and cold to jaundice. Herbal medicines were mostly found to be used by ethnic people to treat cough and cold, joint and body pain, dysentery, throat infection followed by jaundice, fever, constipation, urinary problems, or as a blood coagulant to heal cuts and wounds.

For the preparation of herbal medicine (Table1, Figure 3), leaves (55.56%) were found to be the most frequently used plant parts followed by rhizomes and the whole plant (22.22%, each). Modes of preparation of ethnomedicine include decoctions (66.67%) and pastes (33.33%) and were mostly taken orally (55.56%) followed by topical administration (44.44%) (Table 1).

However, in all the cases the exact method of medicine preparation and dosage of administration were not disclosed as ethnic people believe that disclosure of knowledge to outsiders may damage the effect of the medicine (Mandal et al. 2020a), also the status and importance of medicine men will not be upheld if their secrets were revealed (Mandal et al. 2020b).

CONCLUSION

The district of Cooch Behar of West Bengal is quite rich in pteridophytes. Scientific documentation of the pteridophytic flora in this district is lacking. The present study investigates the epiphytic pteridophyte flora of the district which will help to enrich the database of pteridophytes in India. Documentation of traditional knowledge of ethnic people concerning pteridophytes from the district has been carried out for the first time. Ethnic people are very rich in traditional knowledge which is passed down from one generation to another by verbal means. Documentation of this knowledge is therefore of the utmost importance. Plants are used in the treatment of very common physical ailments and for complex diseases. Further research on medicinal pteridophytes encompassing ethnic knowledge may lead to the development of additional modern drugs and pharmaceutical products.

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COMMUNICATION

Seed germination and storage conditions of *Ilex embelioides* Hook.f. (Magnoliopsida: Aquifoliales: Aquifoliaceae), a threatened northeastern Indian species

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Abstract: *Ilex embelioides* Hook.f. is a threatened tree species endemic to northeastern India. The species propagates naturally through seeds but shows a brief dormancy period. The present study was carried out to assess the germination behaviour, and identify the suitable storage conditions of *I. embelioides* seeds. Results revealed that warm stratification for 30 days could effectively break dormancy. Seeds pre-treated with gibberellic acid (GA_3, 2,000 mg L^{-1}) showed highest germination (63.89 ± 0.91%) as compared to other concentrations of GA_3 as well as potassium nitrate (KNO_3). Highest in vitro seed germination percentage (65.56 ± 2.92%) was recorded on (Murashige and Skoog) MS medium containing 10 mg L^{-1} GA_3. The viability of the seeds declined with storage period irrespective of its storage condition. After 30 days, highest viability (54.72 %) was observed in seeds stored in moist sand at 25°C. Therefore, application of GA_3 and warm stratification (25 ± 1°C) along with a substrate (moist sand) for 30 days may be considered as ideal conditions for effective germination and storage of *I. embelioides* seeds. This study can also be used for mass propagation of the species for reintroduction in the wild.

Keywords: Dormancy, endemic, growth regulators, moisture content, seed storage, viability.

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Author contributions: LM carried out field and laboratory experiments, data analyses and draft manuscript preparation. KU and HC planned the experiments and prepared the final manuscript.

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INTRODUCTION

Ilex embelioides Hook.f. is an endemic (Haridasan & Rao 1985; Lasushe et al. 2022) and 'Vulnerable' species of northeastern India (Mir & Upadhaya 2019). It belongs to Aquifoliaceae (holly) family which comprises of more than 500 species distributed throughout temperate and tropical regions of the world (Galle 1997; Cuenoud et al. 2000). In India, the genus *Ilex* consists of 26 species (Das & Mukherjee 2017). *Ilex embelioides* is a small tree attaining a height of 10 m and is restricted to primary subtropical and tropical forests. The flowering period in the species was observed during rainy season (April–October) and the fruiting occurs during winter season (mid November–January). The seeds remain dormant for about three months (January–March). Seed germination occurs during March–April with the onset of rain (Upadhaya et al. 2017).

The genus *Ilex* has small seeds, globular to oval-oblong rudimentary (underdeveloped but differentiated) embryos that grow inside the seed before the emergence of radicle (Martin 1946; Hu 1975; Baskin & Baskin 2004). The embryo in *Ilex* seeds has low growth potential (physiological dormancy), and warm and/or cold stratification treatments are required to overcome dormancy (Tsang & Corlett 2005; Tezuka et al. 2013). A number of studies have been carried out to understand seed germination and dormancy in other species of *Ilex* such as *I. paraguariensis* (Sansberro et al. 2001; Souza et al. 2022), *I. uaranine*, *I. brasiliensis*, *I. brevicuspis*, *I. uaran* var. *uaranine*, *I. paraguariensis* var. *paraguariensis*, and *I. theezans* (Galindez et al. 2018). However, there is no information on seed germination of *I. embelioides*, which is now facing the threat of extinction due to habitat destruction, overexploitation for use as poles and fuel wood, poor regeneration and possibly climate-related physiological stress (Singh et al. 2023). In order to prevent the species from extinction, mass propagation of the species through seed germination is required (Iralu et al. 2019). Therefore, the present study was carried out to assess the germination behaviour, and identify the suitable storage conditions of *I. embeloides* seeds. Also in vitro seed germination was conducted to identify optimal conditions for germination.

MATERIALS AND METHODS

Matured fruits of *I. embelioides* (Image 1A) were collected from two matured individuals (>5 cm diameter at breast height) from Umtong (25.4124^{0}N & 92.0034^{0}E) and five individuals from Laitryngew (25.2255^{0}N & 91.5475^{0}E) during the month of December 2021. Seeds were separated from the berries and thoroughly washed with water for 10–20 min to remove the pulp. Healthy seeds were separated from damaged or dead seeds using floatation methods (Pipinis et al. 2011). The seeds were disinfected with 75% ethanol for 30 s, and immediately rinsed with sterile water and dried with absorbent paper. The cleaned seeds were stored at room temperature (24 ± 2^{o}C) and later used for various experiments.

Moisture content

To estimate the moisture content, three replicates of 50 seeds each were oven dried at 80°C for 24 h and the final mass was noted. Moisture content was determined following ISTA (2008) as follows:

$$M_c\ (\%) = (W_2–W_3/W_2–W_1)\ x100$$

Where, M_c is the moisture content, W_1 is the weight of the container, W_2 is the weight of the container with seeds before oven drying and W_3 is the weight of the container with seeds after oven drying.

Effect of gibberellic acid (GA_3) and potassium nitrate (KNO_3) on seed germination

Plant growth regulator viz., GA_3, and KNO_3 were used in different concentrations to enhance the germination percentage and reduce the germination time following the protocol as adopted by Iralu & Upadhaya (2016, 2018) and Borah et al. (2023). The different treatments include: (i) control (without GA_3 or KNO_3), (ii) seeds soaked in different concentrations of GA_3 i.e., 200, 500, 1,000, 2,000, 4,000 mg L^{-1} for 48 h, (iii) seeds soaked in different concentrations of KNO_3 i.e., 0.5%, 1%, 1.5% and 2% for 48 h and (iv) seeds soaked in different concentration of GA_3 for initial 48 h and transferred to KNO_3 and kept for another 48 h.

The treated seeds were placed in plastic petri dishes over moist filter paper and kept for germination at 25 ± 1°C. Germination was monitored regularly for a period of 60 days and a seed was considered as germinated with the emergence of a radicle of 1 mm size (Vera et al. 2010). For each replicate in each treatment, the germination percentage was calculated as G = (n/N) × 100, where n is the number of germinated seeds and N is the total number of seeds. Also, the mean germination days were calculated using the formula:

$$\frac{n1+n2+n3+\cdots}{N}$$

Where, n1, n2, n3…. are the number of days taken by individual seeds to germinate and N is the total number

Image 1. A—twig showing *Ilex embelioides* fruit | B—Germination of seeds treated with 2,000 mg L^{-1} GA_3 (C) Seed germination on MS medium containing 10 mg L^{-1} GA_3 (D) Seedling after two months of transplantation in soil. © Leoris Malngiang.

of seeds (Ellis & Roberts 1981).

In vitro seed germination

For in vitro seed germination, the seeds were scarified and soaked in distilled water for 24 h, then washed with 2% sodium hypochlorite for 5 min under aseptic condition, and placed on MS medium (Murashige & Skoog 1962) containing 3% sucrose, vitamins and different concentrations of GA_3 (1 mg L^{-1}, 5 mg L^{-1}, 10 mg L^{-1} and 20 mg L^{-1}). The cultures were maintained at 25 ± 2°C under a 16/8 h photoperiod (flux of 50 µmol $m^{-2}s^{-1}$) of cool white fluorescent lights and in the dark. Germination was monitored for a period of 60 days and the germination percentage was calculated.

Effect of stratification on seed germination

To evaluate the effect of warm and cold stratification on seed germination, three replicates of 30 seeds each were packed in sealed polythene bag containing moist sand and stored at 5 ± 1°C in darkness and in an incubator at a constant temperature of 25 ± 1°C for 0 (control), 10, 20, 30, 40, and 50 days. After each treatment, the seeds were thoroughly washed under tap water and incubated in light at 25 ± 2°C and germination was monitored regularly for a period of 60 days.

Seed viability and storage

To understand the seed viability characteristics, three tests were conducted, viz., seeds (approximately 200 seeds/bag) were stored in airtight containers at room temperature (24 ± 2°C and 65% humidity); seeds were packed in airtight polybags and stored at 5 ± 1°C. In the third and fourth test, moist sand was added and the seeds were stored at a constant temperature of 25 ± 1°C and 5 ± 1°C, respectively. The seeds stored in each of the above conditions were retrieved after 10, 20, 30, and 40 days and the viability test was carried out using the Tetrazolium assay (Enescu 1991).

Data analysis

To compare the effect of different concentration of GA_3 and KNO_3 on seed germination, and different storage conditions on viability of seeds, analysis of variance (ANOVA) followed by Tukey's least significant difference test ($p < 0.05$) was done using Origin Pro 2016.

RESULTS AND DISCUSSION

The moisture content of fresh seeds when dried for 24 h in oven at 80°C decreased by 46.99 ± 0.64%.

A decline in moisture content over a short period of time revealed intermediate nature of seeds (Hong & Ellis 1996; De Vitis et al. 2020). Seed moisture of 10–40% is often considered as desirable for retaining seed longevity in many species (Hampton & Hill 2002; Dadlani et al. 2023).

Plant growth regulator played a major role in breaking seed dormancy in *I. embelioides*. Seeds treated with 2,000 mg L^{-1} GA_3 showed highest germination percentage (63.89 ± 0.91%) and the mean number of days required for germination (16.22 ± 0.87) was also reduced (Image 1B). The use of GA_3 increased the germination percentage of *I. embelioides* during the first four–eight weeks. This result was similar to that observed in *Ilex maximowicziana* (Chien et al. 2011), *I. brasiliensis*, and *I. theezans* (Galindez et al. 2018) where the seeds treated in GA_3 germinated during the first 12 weeks. The decrease in the germination percentage (26.98 ± 1.46%) of *I. embelioides* seeds with the increase of GA_3 concentration (4,000 mg L^{-1}) could be due to the surplus hormone that led to the toxicity of GA_3 (Akbari et al. 2008; Borah et al. 2023).

Though KNO_3 is widely used chemical for enhancing seed germination (Agrawal & Dadlani 1995), it was not very effective in breaking seed dormancy of *I. embelioides* (Table 1). However, when KNO_3 was used in combination with GA_3, the germination percentage increased significantly. This may be attributed to the fact that nitrate reduces abscisic acid concentration in seeds which is responsible for dormancy, whereas GA_3 promotes germination (Hilhorst & Karssen 1992). The germination percentage (46.19 ± 3.59%) of seeds under control condition (soaked in distilled water) took the maximum number of days (39.11 ± 0.40) for germination ($p < 0.05$) as compared to other treatments (Table 1).

Table 1. Effect of GA_3 and KNO_3 on seed germination of *Ilex embelioides*.

Treatments	Mean Germination (Days)	Germination (%)
200 mg L^{-1} GA_3	33.00 ± 0.83 ^{bc}	18.09 ± 1.26 ^{e}
500 mg L^{-1} GA_3	22.89 ± 1.37 ^{d}	42.38 ± 0.48 ^{bc}
1,000 mg L^{-1} GA_3	20.33 ± 0.69 ^{de}	50.98 ± 2.05 ^{b}
2,000 mg L^{-1} GA_3	16.22 ± 0.87 ^{e}	63.89 ± 0.91 ^{a}
3,000 mg L^{-1} GA_3	21.78 ± 0.59 ^{d}	56.04 ± 1.98 ^{b}
4,000 mg L^{-1} GA_3	25.00 ± 1.35 ^{d}	26.98 ± 0.84 ^{d}
0.5% KNO_3	29.78 ± 0.89 ^{c}	36.82 ± 1.37 ^{c}
1% KNO_3	31.22 ± 0.89 ^{c}	39.39 ± 1.16 ^{bc}
1.5% KNO_3	30.89 ± 0.29 ^{c}	36.40 ± 0.41 ^{c}
2% KNO_3	35.78 ± 0.48 ^{ab}	39.01 ± 0.49 ^{c}
200 mg L^{-1} GA_3 + 1.5% KNO_3	24.00 ± 0.69 ^{d}	52.78 ± 0.83 ^{b}
500 mg L^{-1} GA_3 +2 % KNO_3	23.89 ± 0.40 ^{d}	55.84 ± 0.83 ^{b}
Distilled water (Control)	39.11 ± 0.40 ^{a}	46.19 ± 3.59 ^{b}

For each treatment, means followed by the same letter in each column do not differ significantly at $p < 0.05$ (Tukey test).

In vitro seed germination of *I. embelioides* was observed after 40 days of culture both under light and dark conditions (Image 1C). ANOVA of the result revealed that the germination percentage sharply decreased in seeds kept under the dark– as compared to light– conditions (Table 2). The germination percentage (65.56 ± 2.92%) was significantly higher ($p < 0.05$) in seeds cultured in media containing 10 mg L^{-1} GA_3 under light condition. This result was in agreement to the in vitro seed germination observed in *Ilex brasiliensis*, *I. pseudoboxus* and *I. theezans* (Dolce et al. 2015).

Both warm and cold stratification helped in breaking dormancy of *I. embelioides* seeds. Seeds warm stratified (25 ± 1°C) for 30 days showed the highest germination percentage (96.67 ± 1.93%) after 40 days of incubation (24 ± 2°C). However, cold stratification was less effective compared to warm stratification and no germination was observed in seeds stratified for 40 days. Seed viability declined after 50 days of incubation irrespective of the stratification periods (Figure 1). Since embryos of the seeds require relatively high (non–cold stratifying) temperatures for growth, the species showed simple morphophysiological dormancy.

Underdeveloped embryos were observed in cold stratified seeds incubated at 24 ± 2°C for 10 to 40 days. Further, germinated seeds of *I. embelioides* did not exhibit a long (several-week) delay between emergence time of radicle and cotyledon and is a characteristic feature of seeds having non deep simple morphophysiological dormancy. This finding was similar to that reported in *Ilex amara* (Zamith & Scarano 2004), and *I. nitida* (Marrero 1949). The high germination of *I. embelioides* (>80%) when stratified at 25 ± 1°C, was similar to that observed in *Ilex aquifolium*, *I. glabra, I. montana* (Nikolaeva et al. 1985), *I. opaca* (Ives 1923; Barton & Thornton 1947), *I. verticillata* and *I. vomitoria* (Nikolaeva et al. 1985) and *I. maximowicziana* (Chien et al. 2011). Thus, warm stratification could break non deep simple morphophysiological dormancy.

The viability of the seeds declined with the storage period irrespective of how they were stored. However, seeds stored at 25°C with moist sand showed the highest viability percentage (54.72 ± 1.67%) even after 30 days. Whereas, seeds stored in airtight container

Table 2. Seed germination of *I. embelioides* on MS medium with different concentration of GA_3.

Concentration of GA_3 (mg L^{-1})	Light		Dark	
	Mean Germination (Days)	Germination %	Mean Germination (Days)	Germination %
1	45.44 ± 0.56 [a]	40.00 ± 1.92 [b]	46.67 ± 0.88 [a]	14.81 ± 0.98 [ab]
5	41.78 ± 0.80 [ab]	43.33 ± 1.93 [b]	44.11 ± 1.37 [ab]	12.22 ± 1.61 [b]
10	39.78 ± 1.24 [b]	65.56 ± 2.94 [a]	41.78 ± 0.62 [b]	18.15 ± 0.98 [a]
20	44.56 ± 0.78 [a]	35.57 ± 2.22 [b]	46.11 ± 0.97 [ab]	10.74 ± 0.37 [b]

For each treatment, means followed by the same letter in each column do not differ significantly at $p < 0.05$ (Tukey test).

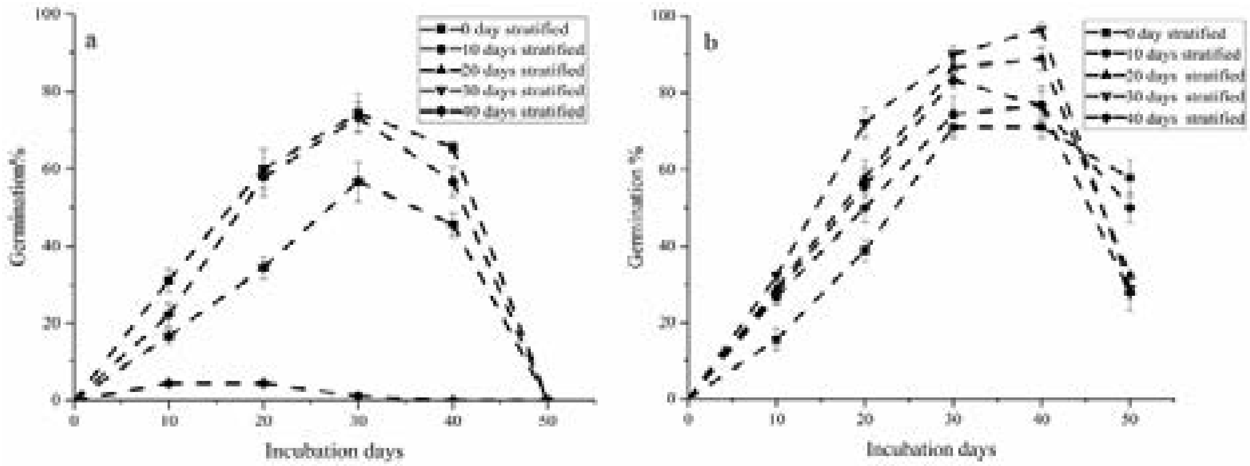

Figure 1. The effect of stratification on germination of *Ilex embelioides* seeds incubated at 25 ± 2°C for 50 days: a—cold (5 ± 1°C) | b—warm (25 ± 1°C).

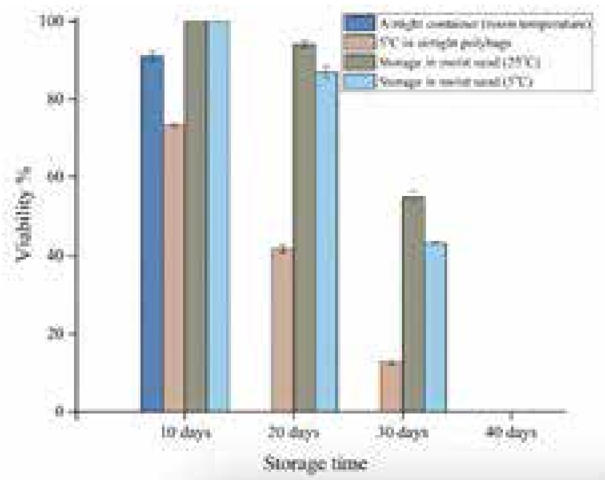

Figure 2. Viability percentage of seeds subjected to different storage conditions.

declined their viability to 91.11 ± 1.00% after 10 days and completely lost viability after 20 days. Viability of the seeds stored in air tight polybag at 5°C declined to 41.67 ± 0.83% and 12.78 ± 0.74% after the 20th and 30th day, respectively. Seeds stored in moist sand at 5°C remained 100% viable after 10 days but the viability declined to 86.94 ± 1.55% and 43.05 ± 0.28% after 20th and 30th days of storage. The comparison of viability percentage of *I. embelioides* seeds subjected to different storage conditions is presented in Figure 2. The low viability of *I. embelioides* revealed that the seeds should be germinated as early as possible.

CONCLUSION

Under natural conditions the low seed germination and high exploitation of *Ilex embelioides* poses a serious threat for its very existence. The seeds of *I. embelioides* exhibit simple morphophysiological dormancy which means the seeds have underdeveloped embryo and physiological dormancy. Application of GA_3 and warm stratification (25 ± 1°C) of seeds for 30 days in moist sand are recommended for germination. The in vitro seed germination experiment has demonstrated that seed cultured on MS medium with 10 mg L^{-1} GA_3 is also effective for mass propagation. Though viability was high in seeds stored at 25°C in moist sand, the viability declined with the storage period. This indicates that the seeds should be germinated as early as possible. The suitable protocols for mass multiplication of the species developed (Image 1D) in the present study would help not only in reducing the germination time but also to obtain large number of seedlings for reintroduction of the species in its natural habitat.

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SHORT COMMUNICATION

Mantispa indica Westwood, 1852 (Neuroptera: Mantispidae), a rare species with some morphological notes from Assam, India

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Abstract: *Mantispa indica* (Westwood) is an insufficiently explored species under the family Mantispidae (Neuroptera) with limited understanding. Its presence has been documented in various regions of India and Nepal over time. Nevertheless, a comprehensive examination of its morphometric characteristics has been lacking. This research presents a novel morphological comparison of male and female specimens, accompanied by appropriate illustrations, from two distinct protected areas in Assam, India.

Keywords: Antenna, Chakrashila, morphological comparison, Neuropteridae, protected areas, sexes.

Abbreviations: OUMNH—Oxford University Museum of Natural History | NHMUK—Natural History Museum in London | ZSI—Zoological Survey of India.

Mantispidae (Leach, 1815) is one of the taxonomically complex, least studied families belonging to the highly diverse order Neuroptera. This group of insects is noteworthy because of their raptorial front legs attached to the anterior margin of an elongate prothorax, they resemble small praying mantids of the order Mantodea, for which they are popularly called false mantids or Mantidfly (Ohl 2007). The overall similarity between mantispids and mantids is clearly due to convergent evolution of morphological similarities of two unrelated insect groups (Cannings & Cannings 2006). In spite of their adaptive significance, this group of insects have received relatively little attention, which is mainly due to less abundance, relatively small number of species and complicated life-cycle (Bhattacharjee et al. 2010). They show hypermetamorphic type of development where, the first instar larvae are campodeiform and quite mobile, and the last two instars are scarabaeiform and relatively immobile (Ghosh 2000; Ohl 2004). In addition, the biology of most species is unknown, those that are known have larvae that feed on Hymenoptera and spiders.

Worldwide, the family Mantispidae represents 410 species, of which 121 species belonging to the genus *Mantispa* are recorded from the Oriental region (Ohl 2007). The Indian Neuropteridae consists of 17 species under seven genera under a single subfamily Mantispinae (Ohl 2007; Chandra & Sharma 2009). The neuropteran fauna of northeastern India was catalogued by Ghosh (2000) represented by two genera: *Climaciella* Enderlein and *Mantispa* Illiger. Ghosh (2000) reported three species of *Mantispa* from the Indian subcontinent, viz.: *Mantispa nodosa* Westwood (present name *Euclimacia nodosa*), *Mantispa indica* Westwood, and *Mantispa rugicollis* Navas. Of late, Sharma & Talmale (2000) reported an unidentified species of *Mantispa* sp. from Tadoba-Andhari Tiger Reserve, Maharashtra,

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India. Bhattacharjee et al. (2010) reported the *Mantispa nodosa* (Westwood, 1847) from West Bengal of India. Ohl (2004) reported the distribution of *Mantispa indica* from Indian oriental, Calcutta, Nepalia. Ghosh (2000) reported distribution of *Mantispa indica* from Assam (Sibsagar), Calcutta, Darjeeling, Meghalaya, Sikkim, western Himalaya, and Karnataka. Very recently, Suryanarayanan & Bijoy (2021) reported *Mantispilla indica* from the Western Ghats in India. But its occurrence in Assam particularly in lower Assam is still doubtful as there is no sufficient supporting literature against it. Thus, the present paper provides first record from this area with some standard measurements of body parts following Ohl (2004) that facilitate future comparison with other species in Mantispa.

Materials and Methods

Male and female individuals were collected from two different localities (Male 26.429^{0}N and 90.444^{0}E) Female (26.736^{0}N & 90.472^{0}E) during the year 2018 and 2020. The female was collected on a hot sunny day of June 2018, around 1400–1500 h in Ultapani Reserve under Haltugaon forest division while the male was collected by light trapping using a CFL bulb hung against a white sheet of cloth in August 2020 in Chakrashila Wildlife Sanctuary of Assam. The mantispid was hovering over the bulb at 1900–1930 h and captured by insect net. Both the samples were preserved in 80% ethanol following Ghosh (1998) and stored for future reference in the laboratory of Ecology and Wildlife, Department of Zoology, Bodoland University, Kokrajhar, Assam. The species was identified following available literature and comparing with the samples of Hope Entomological Collection, Oxford University Museum of Natural History (Tauber et al. 2019). Images were captured by Zoom Stereo Microscope LB-340 and Canon EOS 500D. The measurements are in millimetre made with an eyepiece graticule following the software MICAPS MICAPS-MicroView.

Nomenclature: The name is now the same as the original, and it is listed as such by Ohl (2004: 184). For a while, the species was known as *Mantispa* (*Mantispilla*) *indica* (Westwood) [combination by Enderlein (1910: 346)]. Later, the name *Mantispilla* was synonymized with *Mantispa* by Penny (1982: 217).

Type species: Westwood's description mentioned two depositories (British Museum and his own collection), and Ohl (2004: 184) reported seeing types at the OUMNH and the NHMUK. Two types (sexes unconfirmed, one probably female) are in the OUMNH (NEUR0005-01, -02; Figures 55, 56) (Tauber et al. 2019).

Distribution: *Mantispida indica* was previously recorded in some places in India and Nepal. Among these, Kolkata and Darjeeling of West Bengal, East Garo Hills of Meghalaya, Sikkim, Sibsagar of Assam, Mysore of Karnataka, Jodhpur of Rajasthan, Kangra Valley in Himachal Pradesh (Ghosh & Sen 1977; Ghosh 1998, 2000; Sharma & Chandra 2013). Very recently, it was also cited from Western Ghats (Suryanarayanan & Bijoy 2021).

Habit and Habitat: The female was reported while seating on a tender leaf of *Sida* sp. on the road side where the upper canopy was open. The individual was found immovable for about 10 minutes before capture. Perhaps the individual was waiting for its prey. On the other hand, male was attracted towards the CFL bulb while light trapping and hovering over the bulb. The habitat was mostly dominated by the Sal trees *(Shorea robusta*) along with bamboo patches. Flying and walking pattern was observed and recorded inside the rearing box (1.5 x 1.5 x 1.5 ft). They usually do not fly for long distance and while flying they resemble to the wasp species. Besides, they walk within a short distance with the help of meta and meso-thoracic pair of legs. Antennas are moving straight up and down movement. Like other neuropteran insects the mantispids are also solitary in nature. Besides, their peculiar lifecycle, solitary nature and extremely low abundance they are very difficult to recognise in nature.

Diagnosis of sexes

Female: Pronotum dorsally yellow but ventro-laterally dark brown. Black lines in the margin of precoxa and coxa are distinct. Abdomen eight segmented with dark brown lines at the junction of each tergite. Yellow band of antenna are absent. Underside of femur is blackish-brown. Abdomen is comparatively larger than the male (Image 1).

Wings: Hyaline; veins black; radius yellow; pterostigma elongate and red; with 7–8 oblique discoidal cells. In genus *Mantispa* only one row of discal cells presents in both wings (Aspöck & Aspöck 1994).

Measurements and ratios (in mm) of male and female: A few measurements were depicted of male and female for a more detailed description (Table 1). For convenience, Lambkin (1986) abbreviations are added in brackets after the descriptions (e.g., minimum frontal eye distance [WBE]").

Male: Body dark brown and slander. Lower part of the abdomen yellowish with eight abdominal segments. Abdomen dorso-ventrally flattened with prominent terminal gonocoxaite. Pronotum dark brown. Underside

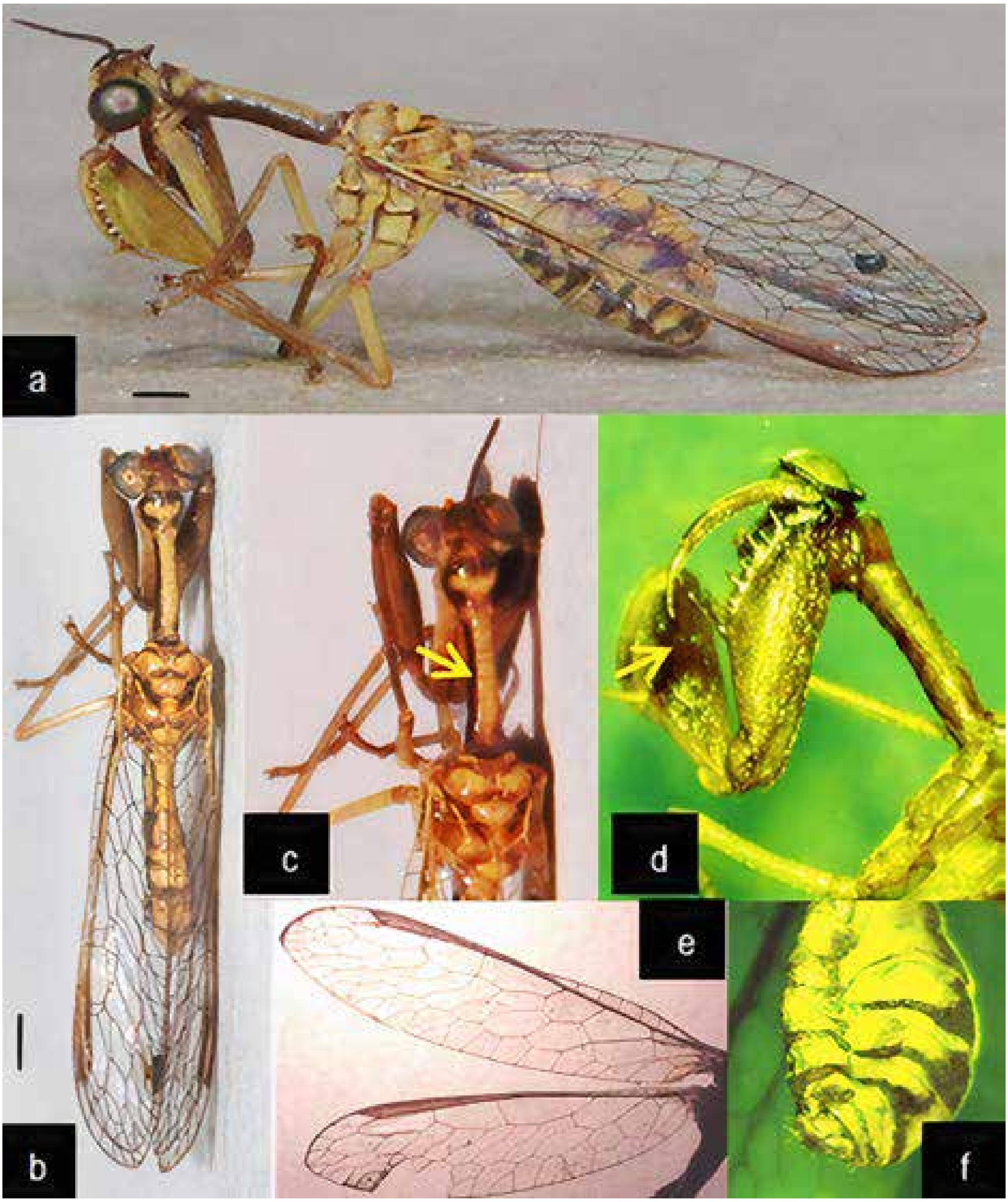

Image 1. Images of female *Mantispa indica* (a–f): a—General habitus from lateral | b—General habitus from dorsal | c—Head and thorax, from dorsal (presence of lateral line in thorax) | d—Left foreleg, from inner view (inside of the femur is blackish brown) | e—Left fore and hind wings | f—Abdomen, from ventral. Scale bar = 1.0 mm. © Kushal Choudhury.

of femur is blackish-brown. Antenna consists of 28 articles with a distinct yellow band. Black line in the margin of precoxa and coxa are absent (Image 2).

Wings: Hyaline; veins black; radius yellow; pterostigma elongate and brown; with 7-8 oblique discoidal cells.

Table 1. Measurements and ratios of male and female *Mantispa indica*.

Parameters	Male (mm)	Female (mm)
Minimum frontal eye distance [WNE]	0.51	0.97
Maximum frontal head width including eyes [WAE]	2.06	2.22
Pronotal length, measured along dorsal midline [LP]	3.14	3.71
Maximum pronotal width: near head / near meso-thorax /middle at least thick part	1.03/ 0.62/0.46	1.13/0.81/0.41
Maximum fore femoral length [LFF]	4.39	3.19
Maximum fore femoral width [WFF]	1.45	1.24
Fore femoral ratio (length : width) [LFF : WFF]	3.02	2.56
Maximum mid femoral length [LMF]	2.79	2.29
Mid femoral ratio (mid femoral length: head width including eyes) [LMF : WAE]	1.35	1.03
Maximum forewing length [LFW]	10.16	11.46
Maximum forewing width (measured near pterostigma) [WFW]	3.06	3.02
Forewing ratio: (length : width) [LFW : WFW]	3.32	3.79
Maximum hind wing length	9.1	9.94
Maximum hind wing width	2.68	2.83
Hind wing ratio (length : width)	3.39	3.51
Total body length (excluding appendages)	10.45	11.28
Antenna segment	28	Damaged
Meso-thorax	1.29 (B)/1.02(L)	1.70 (B)/1.25 (L)
Meta-thorax	1.15 (L)/ 0.80 (B)	1.70 (B)/0.98 (L)
Spines	Long-1; Middium-3; Small-14	Long-1; Middium-3; Small-12

B—Breath | L—Length.

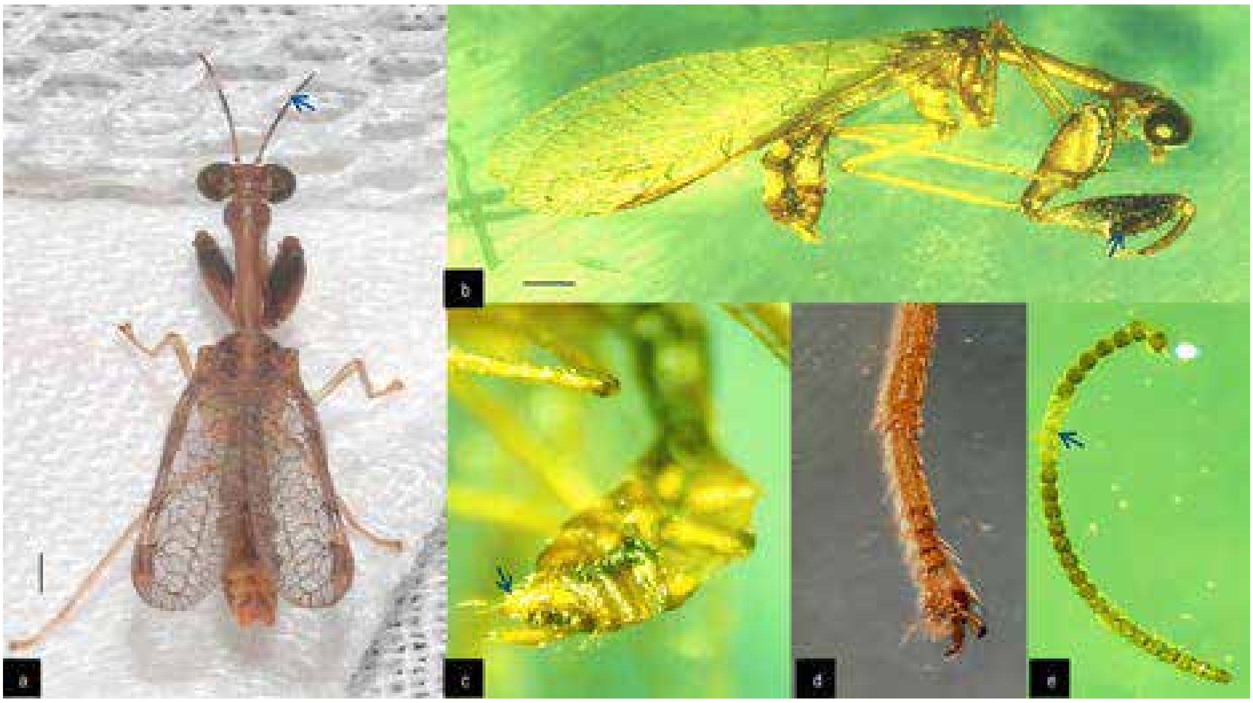

Image 2. Photographic images of male *Mantispa indica* (a–e): a—General habitus from the dorsal | b—General habitus from lateral (femur inside darker) | c—pointing out Gonocoxite | e—lighter region of antenna segments. Scale bar = 1.0 mm. © Kushal Choudhury.

Conclusion

Northeastern India is a biodiversity hotspot with a large number of endemic elements within its fauna and flora. But order Mantispidae was poorly documented from this region. Though the species are solitary, low abundance and obscure in nature, the occurrence of both male and female individuals from two different locations indicates the presence of more Mantispidae than presently known. Accordingly, extensive survey and collection is needed throughout the region so as to further expand our knowledge of the diversity, conservation status as well as to discover the biology of these fascinating species.

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OPEN ACCESS

NOTE

Auto-fellatio behaviour observed in the Indian Palm Squirrel *Funambulus palmarum* (Linnaeus, 1766)

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Masturbation is an auto-sexual behaviour, a widespread phylogenetic trait in many taxa, including non-mammalian species (Roth et al. 2022). Non-reproductive sexual behaviours are observed in birds, Bonobos, sheep, goats, cats, Cape Squirrels, Spotted Hyenas, and many other animals (Bagemihl 1999; Schwartz 1999; Waterman 2010; Balcombe 2011). Waterman (2010) reported that males under intense sperm competition might manipulate sperm quantity and quality through masturbation, which could waste sperm and decrease fertility. Masturbation is found to be a reason for lacking sexual opportunity or fulfilling sexual desire. Masturbation, however, was initially thought to be non-adaptive, but later researchers pointed out to be adaptive (Thomsen et al. 2003). Sperm flushing through masturbation is adaptive to increase the chance of having fertile sperm to have reproductive success (Baker & Bellis 1993; Bellis 1995). Masturbation is a self-directed action; the vertebrates use their hands directly and sometimes mouth by the suggestive term auto-fellatio (Waterman 2010). Extending to body parts, monkeys have been known to masturbate using stones as a part of tool use based on physiological responses (Cenni et al. 2022).

The Indian Palm Squirrel *Funambulus palmarum* is a rodent under the family Sciuridae and is widespread in the Indian subcontinent and Sri Lanka (Nowak 1999). They are known to breed throughout the year (Prasad 1951). Rodents perhaps exhibit masturbation behaviour; one such incident has been reported in the African Ground Squirrel *Xerus inauris* (Waterman 2010). This study presents an observation of auto-fellatio behaviour in an adult male Indian Palm Squirrel.

On 14 December 2018, an Indian Palm Squirrel was found on a Neem Tree *Azadirachta indica* during the evening hours in an agriculture field at Bhavanisagar, Tamil Nadu, India (11.4783^{0}N, 77.1273^{0}E). The squirrel's activity was observed to express an auto-fellatio behaviour (Image 1). The observation began with the male squirrel stimulating its genital organ using both hands for approximately six seconds.

The activity continued till the penis got appropriately erected. The squirrel held its penis by its forelimbs and was sucked by its mouth forward and back

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Image 1a. *Funambulus palmarum* engaging in auto-fellatio activity.

Image 1b. *Funambulus palmarum* engaging in auto-fellatio activity.

continuously. Subsequently, the sperm ejaculated at the end of the 26th second, and thereby we concluded it as masturbation. The action was performed with its whole mouth for 26 seconds, confirming the activity as an auto-fellatio behaviour and not a penis-cleansing behaviour. The male squirrel was found alone without any other individuals near for about a 10-m radius from the animal.

The auto-fellatio behaviour in animals has been attributed to various hypotheses, including relaxation and aggression reduction (Thomsen & Sommer 2015), serving as a sexual outlet, potential enhancement of sperm quality, energy reallocation, sexual display, rivalry demonstration, and even reduction of the risk of sexually transmitted infections (Waterman 2010). Considering that Indian Palm Squirrels are known to breed throughout the year, any of these hypotheses could potentially explain the occurrence of auto-fellatio behaviour in this species.

This observation calls for further research to comprehensively investigate the variety of factors contributing to non-breeding behaviours in Indian Palm Squirrels. The auto-fellatio behaviour observed in *F. palmarum* is novel and represents the first recorded instance to the best of our knowledge. Additional studies are needed to delve deeper into the motivations and implications of this behaviour, shedding more light on its significance within the context of squirrel biology and behaviour.

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NOTE

A novel anti-predatory mechanism in *Indrella ampulla* (Gastropoda: Ariophantidae)

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Indrella ampulla (Benson, 1850) is a large-bodied terrestrial air-breathing gastropod mollusc belonging to the family Ariophantidae. It is endemic to the Western Ghats of peninsular India (Benson 1850; Blandford and Godwin-Austen 1908). *Indrella* is a monotypic genus comprising of polymorphic variants spatially separated across the Western Ghats. It is generally found in the wet evergreen forests and different plantations areas of the central and southern Western Ghats (Narayanan & Aravind 2021).

In this note we report the smearing behaviour as a novel anti-predatory strategy followed by these large gastropods as an extension of the frothing behaviour reported earlier. Three individuals of *Indrella ampulla* (two yellow morphs and one orange morph) were observed after agitating them by hand on 25 June 2022 at 12:44 h and 14 July 2022 at 15:41 h. All three individuals were fairly aggressive in terms of their defence mechanism by producing froth along with a slimy secretion to cover their shell. The observations were made in Wayanad in the state of Kerala (11.5144°N and 76.0389°E, 838 m) and in Coorg in the state of Karnataka (12.2283°N and 75.6542°E, 1,088 m) in India. All the observations were made on private properties.

The observations were made while assessing the microhabitat preference of land snails in the Western Ghats. Two of the individuals (yellow morph of *Indrella ampulla*) were agitated by hand in Lakkidi to observe their behaviour when subjected to stress; these individuals were found on different substrates – one on a rock and the other on a tree trunk. We observed that both individuals secreted foam that was viscous and sticky in nature. Upon detection of physical stress, the individuals stopped their movement and started smearing their slime on their shell with the tail end of their body until the potential threat was over (Figure 1; see Video 1). Such response was only observed upon overstimulating the animal. The source of the secreted foam was observed to be the surface of the mantle mucus cells (Rollo & Wellington 1979) (Image 1; Video 2). A similar behaviour was also observed in case of the orange individual in Coorg. The agitation experiments were performed by KM in all three cases.

Frothing behaviour was earlier reported as a defence mechanism in the red morph of *Indrella ampulla* during an observation of a cane turtle feeding on one of the individuals (Deepak & Vasudevan 2009). Here for the first time, we observed similar occurrences in the yellow and the orange morph as well. Foaming as an anti-predatory strategy was also reported earlier in

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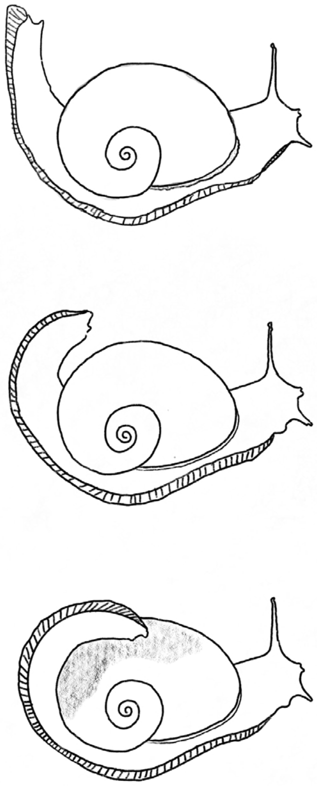

Figure 1. Diagrammatic representation of an Individual of *Indrella ampulla* trying to smear its slime on its shell by using the tail end of the body. © Karunakar Majhi

several other species of terrestrial gastropods such as *Helix pomatia* (Pollard, 1975), which when attacked produced a copious amount of froth. Exudation of slime is also studied in many slugs such as *Arion fasciatus* and *Deroceras reticulatum*, the sticky slime makes slugs a difficult prey (Pakarinen 1994; Mair & Port 2002). Certain other species of terrestrial snails such as *Karaftohelix editha* and *Karaftohelix gainesi* swing their shells in order to get rid of the predators (Morii et al. 2016). *Ovachlamys fulgens*, also known as the jumping snail, propels (jump) its body when disturbed (Teixeira et al. 2017). *Cantareus apertus* rocks its shell back and forth to produce sound (Wenger 2014).

In case of *Indrella ampulla*, smearing the slime over the shell with the tail also serves as a defence mechanism, potentially covering the animal completely with slime to deter predators. It is a large-bodied semi-slug like animal which requires an effective strategy to avoid predation since it cannot retract its entire body into the shell to protect itself. Similar observation and assessing the nature of the secretion and the trait governing it may also provide important insights to the mechanisms of defence.

Image 1. Two individuals of *Indrella ampulla* producing foam after being disturbed. © Karunakar Majhi

Video 1. An Individual of *Indrella ampulla* spreading its slime on its shell. © Karunakar Majhi.

Video 2. An individual of *Indrella ampulla* secreting foam from the surface of the mantle. © Karunakar Majhi.

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NOTE

Hedychium coccineum Buch.-Ham. ex Sm. (Zingiberaceae): an addition to the flora of Andhra Pradesh, India

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The genus *Hedychium* J. Koenig belongs to the family Zingiberaceae; members are commonly referred to as ginger lily or butterfly lily. One-hundred-and-one accepted species occur in different parts of the World (POWO 2023), and according to Singh & Srivastava (2020) India has 42 taxa (40 species and two varieties). Recently, Sabu & Hareesh (2020) reported one more new species *Hedychium mechukanum* M. Sabu & Hareesh*,* from the eastern Himalayan region of India. Sabu (2006) reported five species from southern India and Pulliah & Karuppuswamy (2020) reported three species from the Eastern Ghats. Only two species: *H. coronarium* J. Koenig and *H. flavescens* Carey ex Roscoe, were reported from Andhra Pradesh (Pullaiah 1997).

During our explorations in the Eastern Ghats of Andhra Pradesh in the month of August 2021 (Figure 1), the first author found an interesting *Zingiber* inflorescence with dense, bright red flowers. After essential taxonomical studies, it was identified as *Hedychium coccineum* and found that it was not reported from Andhra Pradesh state. It is the first kind of report from the state of Andhra Pradesh and collected specimens were deposited at the Herbarium of Department of Botany (AUV), Andhra University (Image 2). Some of the rhizomes were collected from the study site and introduced into the Andhra University Botanical Garden for further studies. A brief description, photo graphs, and ecological information are provided in this article for easy identification.

Taxonomic treatment

Hedychium coccineum Buch.-Ham. ex Sm.in Rees, Cycl. 17: no. 5. 1811; Singh & Srivastava Fl. Pl. India Annot. Checkl. (Monocot.): 126. 2020. *Hedychium angustifolium* Roxb. ex Ker Gawl., Bot. Reg. 2: t. 157.1816, nom. illeg. *Hedychium coccineum* var. *angustifolium* Baker, Fl. Brit. India 6: 231. 1892, nom. invalid. *Hedychium coccineum* var. *roscoei* Wall. ex Baker in Hook.f., Fl. Brit. India 6: 231. 1892. (Image 1).

Common name: Scarlet gingerlily , Orange gingerlily, Orange bottlebrush ginger.

Local name: 'Chalavadumpa' (Telugu).

Description: A large perennial rhizomatus herb. Rhizomes usually shows monochasial helicoid branches, slightly aromatic, ca. 4 cm width when cross section. Aerial pseudo stem (leafy shoot), cylindric, covered by purple sheaths, grows up to 3 m height. Leaf bases attenuate, forms pesudo stem, ligule looks like human nails, light pink or pale red tinged, ca. 2.7 cm. Lamina oblong-lanceolate or narrowly linear glabrous, apex

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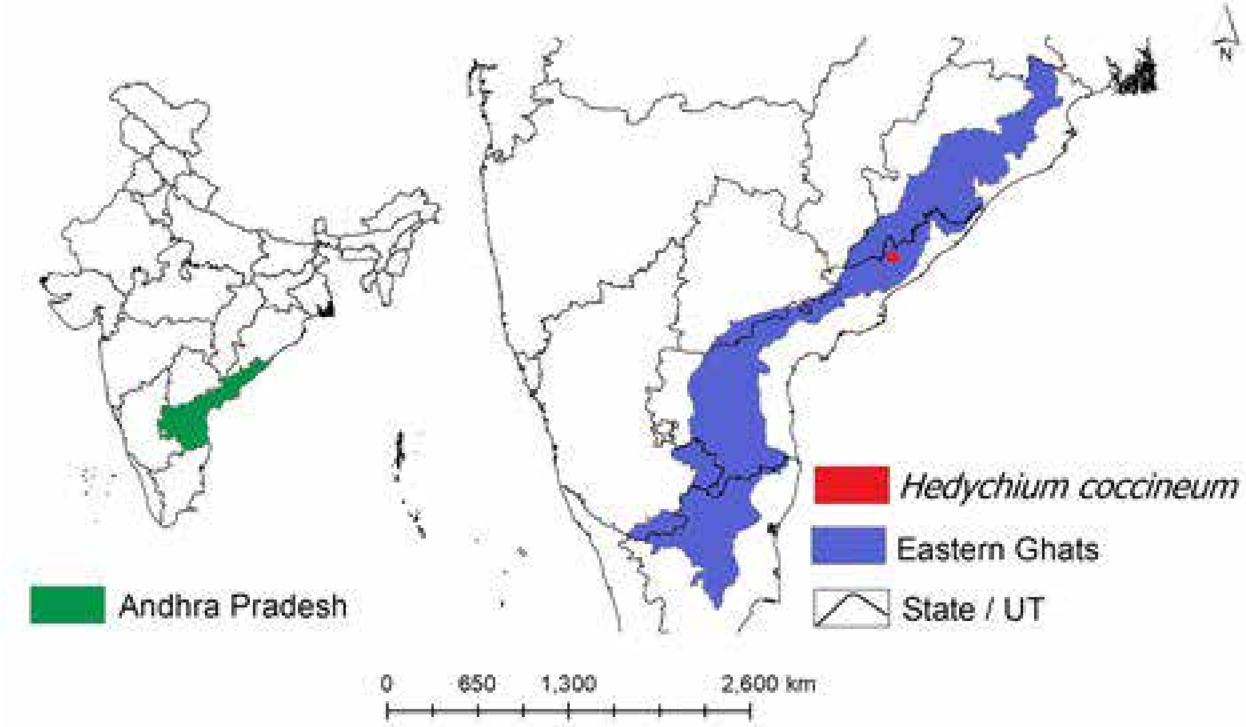

Figure 1. Location map of *Hedychium coccineum*.

caudate-acuminate, 25–50 × 3–5 cm, dark green adaxial and light purple abaxial. Inflorescence terminal spikes, ca. 30 cm long. Spikes cylindrical, slightly villose, densely flowered. Bracts arranged in vertical rows, outer bract coriaceous, oblong, ca. 3.5 cm long, tubular, glabrous sometimes slightly pubescent, usually green, rarely purple tinged at base, margin involute, apex obtuse; inner bract ca. 2.5 cm, ovate-oblong, tip slightly toothed. Bracteoles broadly ovate, ca. 1.5 cm. Flowers bright red, ca. 5 cm long, fragrant. Calyx ca. 2.5 cm long, sparsely pubescent. Corolla tube longer than calyx, ca. 2.8 cm long; lobes reflexed, linear-lanceolate, ca. 3–3.8 cm long. Lateral staminodes petaloid, lanceolate, ca. 2.3 cm long. Labellum orbicular, ca. 2 cm in diameter or rather small, apex deeply 2-cleft. Filaments ca. 5 cm long; anthers 7–8 mm long. Ovary 2.5–3 mm long, pale yellow, hairy, numerous ovules arranged by axil placenta. Style long filiform, cup-shaped, stigma hairy.

Flowering and Fruiting: Flowering–June to May, fruits not seen.

Specimen examined: 23398 (AUV) 30-viii-2021, India, Andhra Pradesh, Visakhapatnam district, Rolangiputtu Village, Coll. P. Janaki Rao.

Habitat and species association: Rarely found along the stream banks in semi evergreen forest patches with an association of ferns and angiosperms such as trees: *Antidesma ghaesembilla* Gaertn., *Callicarpa tomentosa* (L.) L., *Diospyros sylvatica* Roxb., *Chloroxylon swietenia* DC., *Kydia calycina* Roxb., *Mallotus philippensis* (Lam.) Müll.Arg., *Mangifera indica* L., *Murraya koenigii* (L.) Spreng., *Neolitsea foliosa* (Nees) Gamble, *Psydrax dicoccos* Gaertn.; Shrubs: *Ageratina adenophora* (Spreng.) R.M.King & H.Rob, *Ardisia solanacea* Roxb., *Chromolaena odorata* (L.) R.M.King & H.Rob*., Clausen aheptaphylla* (Roxb.) Wight & Arn., *Colebrookea oppositifolia* Sm., *Dendrolobium triangulare* (Retz.) Schindl., *Lantana camara* L., *Melastoma malabathricum* L., *Solanum torvum* Sw., *Persicaria glabra* (Willd.) M.Gómez, *Pogostemon benghalensis* (Burm.f.), *Rubus ellipticus* Sm.; Climbers: *Ampelocissus latifolia* (Roxb.) Planch., *Cissus repens* Lam., *Combretum albidum* G.Don, *Gynochthodes umbellata* (L.) Razafim. & B.Bremer, *Piper longum* L.; Herbs: *Ageratum conyzoides* L., *Centella asiatica* (L.) Urb., *Commelina longifolia* Lam., *Ensete glaucum* (Roxb.) Cheesman, *Globba marantina* L., and *Hedychium flavescens* Carey ex Roscoe.

Distribution: Native to India, Bangladesh, Bhutan, China, Myanmar, Nepal, Thailand, Tibet, and Vietnam. This species is introduced into Caroline Is., Cuba, Jamaica, Mauritius, Réunion, Sri Lanka, and Trinidad-Tobago (POWO 2023). In India, this species is distributed in Arunachal Pradesh, Assam, Bihar, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Sikkim, Uttarakhand, and West Bengal (Singh & Srivastava

Image 1. *Hedychium coccineum*: a—Whole plant | b—rhizome | c—cross section of rhizome | d—adaxial surface of leaves | e—abaxial surface of leaves | f—ligule | g—inflorescence | h—inflorescence after flowering. © J. Prakasa Rao & P. Janaki Rao.

Image 2. Herbarium of *Hedychium coccineum*. © J. Prakasa Rao.

2020).

Ethno medicine: Raw tender aerial stems are eaten by local people during the summer and fresh rhizome juice is used as cooling agent.

Among the 43 taxa (41 species and two varieties) from India, a majority of *Hedychium* species are found in northeastern India (Sanoj 2011), and the Eastern Ghats region has only three: *H. coccineum* Buch.-Ham. ex Sm. *H. coronarium* J. Koenig and *H. flavescens* Carey ex Roscoe (Rao et al. 2016; Pulliah & Karuppuswamy 2020). The present report of *H. coccineum* from Andhra Pradesh is a new record for this species in the Eastern Ghats region.

Many places in the Eastern Ghats are potential sites for Zingiberaceae members including *Hedychium* species, and there is a need to investigate on diversity, distribution, and conservation status of zingibers in the

Eastern Ghats region. *Hedychium* species are generally used as medicine by the local people and these plants have horticulture importance with bright flowers. Consumption of these fresh materials by the local people should be studied in scientific manner to know the useful and harmful effects.

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